# ENERGY UTILIZATION AND NITROGEN RETENTION BY SWINE AND RATS FED RATIONS VARYING IN ENERGY AND PROTEIN LEVEL

by

HENRY J. A. LIKUSKI

JULY, 1959.

THE UNIVERSITY OF ALBERTA

# ENERGY UTILIZATION AND NITROGEN RETENTION BY SWINE AND RATS FED RATIONS VARYING IN ENERGY AND PROTEIN LEVEL

A DISSERTATION

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF ANIMAL SCIENCE

by

HENRY J. A. LIKUSKI

EDMONTON, ALBERTA

JULY, 1959

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Energy Utilization and Nitrogen Retention by Swine and Rats Fed Rations Varying in Energy and Protein Level" submitted by Henry J. A. Likuski, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science

ENERGY UTILIZATION AND NITROGEN RETENTION BY SWINE AND RATS FED RATIONS VARYING IN ENERGY AND PROTEIN LEVEL

## ABSTRACT

These experiments were designed to study the effect that feeding rations varying in energy and protein level had on energy and nitrogen digestibility and nitrogen retention by weanling rats and growing swine. A 2 x 2 factorial design using rations containing gross energy levels of 3.2 and 3.9 Cal./gm. and crude protein levels of 14 and 18% was used for the major studies. Rate of gain and efficiency of feed utilization by swine fed these rations from weaning to market weight, and carcass characteristics of the market swine were also studied.

Twenty percent Terralite, a fine aggregate of vermiculite, was used to lower the digestible energy content of the rations. In the rat trial Terralite compared favourably with Alphacel, a non-nutritive cellulose, previously used as a diluent in studies of this nature with rats.

The apparent digestibility of energy and nitrogen by rats and swine were similar. Although swine digestibility figures varied with the age of the pig, the average was near that obtained for weanling rats. Nitrogen digestibility decreased for both species when a diluent was used to lower the energy content of the ration.

As the diets had energy-protein ratios below that required for maximum nitrogen utilization by rats, nitrogen retention as a percentage of gross or digestible nitrogen was low for all diets used in the rat trial. On the basis of nitrogen retention weanling pigs, however, required a higher level of protein in their ration than was required by

weanling rats. In the trial with 15 lb. pigs the percent nitrogen retention was increased by raising the protein level of the ration. At later stages of growth nitrogen retention appeared to decrease when high levels of protein were fed.

Rate of gain and feed efficiency in pigs from weaning to market weight were improved by feeding high levels of protein during early stages of growth, and by increasing the energy level of the ration at later stages. Feeding high levels of protein during the finishing period decreased rate of gain and efficiency of feed utilization.

Carcass quality was not seriously affected by feeding high energy rations when they contained corresponding high levels of protein. However, pigs fed low energy rations did have the superior carcasses.

During the later stages of growth male pigs made faster weight gains than females. Female pigs, however, excelled males in all carcass characteristics measured.

ACKNOWLEDGMENTS

The author wishes to thank Dr. J. P. Bowland, Associate Professor of Animal Husbandry, for his helpful advice during the course of this study and for his constructive criticisms and suggestions in connection with the preparation of this manuscript. Thanks are also extended to Dr. L. W. McElroy, Head of the Department of Animal Science, for use of the facilities of the Department. The aid of Dr. R. T. Berg, Associate Professor of Animal Husbandry, and Dr. S. Zalik, Associate Professor of Plant Physiology and Biochemistry, in carrying out the statistical analysis is gratefully acknowledged.

Acknowledgment is also made of the cooperation of the Livestock Division, Production and Marketing Branch, Canada Department of Agriculture, in cutting and scoring carcasses by Advanced Registry standards.

This project was supported in part by a grant from the Prairie Regional Laboratory of the National Research Council.

TABLE OF CONTENTS

LIST OF TABLES

# ENERGY UTILIZATION AND NITROGEN RETENTION BY SWINE AND RATS FED RATIONS VARYING IN ENERGY AND PROTEIN LEVEL

## INTRODUCTION

Feeding swine high energy rations which have been properly balanced with protein, as well as minerals and vitamins, may result in improved feed efficiency and a faster rate of gain without seriously affecting carcass quality. This concept of a correct adjustment between protein and energy is not new; however, it has been given new emphasis in recent years.

The following study was carried out from May, 1958 to June, 1959. It was conducted in order to obtain information pertaining to the effect that rations varying in energy and protein level have on energy and nitrogen digestibility and nitrogen retention in growing pigs from weaning up to 110 lb., and on rate of gain, efficiency of feed utilization and carcass characteristics of pigs from weaning to market weight.

In addition to the work with swine, rat studies were conducted to obtain preliminary data on the value of different products as diluting materials to lower the digestible energy content of the diet. This trial also supplied information on the comparative results from digestibility and retention studies with the two species, swine and rats.

## REVIEW OF LITERATURE

During the past several years, research has been very active in the field of energy and protein relationships. The following review is divided into two sections; (1) laboratory animals, poultry and humans, and (2) swine. As the research carried out was primarily concerned with swine the first section is reviewed very briefly.

### (1) LABORATORY ANIMALS, POULTRY AND HUMANS

Relatively smaller costs as well as a shorter life cycle have often resulted in research being carried out with laboratory animals in advance of farm livestock. Such is the case in metabolism studies dealing with energy and nitrogen relationships.

In order to vary the ADE* content of diets, diluents may be used. Sibbald (1957) used Alphacel, a non-nutritive cellulose, for this purpose. Other workers (Mraz *et al.*, 1957) have used sand and vermiculite in poultry studies.

Work with dogs (Cowgill, 1928), rats (Adolph, 1947; Kennedy, 1952-1953; Sibbald *et al.*, 1957, 1957b) and chicks (Hill and Dansky, 1950, 1954; Dansky and Hill, 1951; Peterson *et al.*, 1954) has established that any decrease in the ADE of a diet is compensated for by increased food consumption. Breeding turkeys, however, do not eat primarily to satisfy their energy requirements (Robblee and Clandinin, 1959).

Decreased nitrogen utilization during caloric restriction has been reported in humans (Schwimmer and McGavack, 1948; Leverton *et al.*,

---

*The following abbreviations will be used throughout this thesis: ADE - apparent digestible energy; ADN - apparent digestible nitrogen, HE-HP - high energy-high protein; LE-LP - low energy-low protein; LE-HP - low energy-high protein; HE-LP - high energy-low protein.

1951), dogs (Allison, 1951; Rosenthal and Allison, 1951), mice (Bosshardt and Barnes, 1946; Fenton and Marsh, 1956), rats (Bosshardt and Barnes, 1946; Stevenson et al., 1946; Benditt et al., 1948; Pike et al., 1954; Calloway and Spector, 1955; Forbes and Yohe, 1955; Rosenthal and Allison 1956; Sibbald et al., 1956, 1957) and poultry (Sunde, 1956; Donaldson et al., 1956). Animals will utilize food protein to satisfy their energy requirements when low levels of non-protein calories are fed (Pollack, 1954).

In rat studies Sibbald et al., (1957) have shown that the percentage of nitrogen retained is controlled by the ratio of ADN to ADE in the diet. Sure et al., (1957) also working with rats, found protein efficiency to decrease with increased protein intake as a result of the greater waste in nitrogen metabolism with the increased ingestion of protein. Forbes et al. (1958) working with growing albino rats, showed that as the rate of nitrogen absorbed increased the nitrogen balance increased at a decreasing rate. This supports earlier work with adult dogs (Allison and Anderson, 1945) in which the relationship between nitrogen balance and absorbed nitrogen was found to be linear in the region of negative nitrogen balance, the linearity often extending over on the positive side, but becoming obviously curvilinear well on the positive side of nitrogen balance.

For a more complete review of the literature published concerning food consumption, nitrogen retention and carcass composition as related to calorie:protein ratios in animal diets reference is made to Sibbald's Doctorate thesis (1957).

(2) SWINE

A. ENERGY AND NITROGEN DIGESTIBILITY AND NITROGEN RETENTION

One of the first metabolism studies with swine was conducted by Mitchell and Hamilton in 1935. In pigs weighing about 100 lb., these workers found a higher nitrogen retention as the percent of protein in the ration increased from 9 to 20 or 25 percent. At heavier weights, 15 percent protein was found to be as good as 18 percent using nitrogen retention as the criterion of adequacy.

Mitchell and Hamilton reported that the digestibility of the protein fraction was not affected by the protein level. This is in contrast to a later report (Lloyd and Crampton, 1955) in which increasing the protein percentage or decreasing the crude fiber percentage of a ration was found to have a tendency to increase the apparent digestibility of protein. In another report Crampton *et al*. (1955) explained that the biological (replacement) value of protein contained in malt sprouts was lower than that of linseed oilmeal protein, not because of the difference in protein quality, but because the low digestibility of the crude fiber in malt sprouts resulted in a low apparent digestibility of malt sprouts protein.

Bell *et al*. (1951) presented data to show that the biological value of protein fed at a level of 10% of the total ration decreased as the weight of the pigs increased. This work was supported by Reber *et al*. (1953) who found that the biological value of casein decreased as the level of protein in the ration was increased and as the pigs increased in body weight.

The conducting of metabolism studies, where accurate separation of excreta is required, frequently presents caging problems. Rectangular-

type metabolism cages have been successfully used for pigs over 50 lb. (Crampton and Whiting, 1943; Watson _et al._, 1943; Hussar, 1958), while use of adjustable cylindrical cages has been suggested for smaller pigs (Bell, 1948). The use of swine harness (Kolari _et al._ 1955; Hussar, 1958) has simplified the separation of excreta from male baby pigs.

B. RATE OF GAIN, FEED EFFICIENCY AND CARCASS CHARACTERISTICS

In an excellent review of factors affecting rate of gain, feed efficiency and carcass quality in swine, Tribble _et al._ (1956) stated that as early as 1909 Forbes recognized nutrition to have an important effect on the composition of the hog carcass. Today, research workers (Bowland and Berg, 1959) are considering the possibility of establishing an optimum ratio between dietary energy and nitrogen in swine rations, which would be similar to that demonstrated for the weanling rat (Sibbald _et al._ 1957) and chick (Hill and Dansky, 1950). These workers state that "in establishing such an optimum ratio it is necessary to define the criterion of measurement in hogs, as rate of gain and efficiency of feed utilization may have different protein-energy optima to that required for high carcass quality".

It has been found that when isocaloric rations of varying protein level were fed to swine that rate of gain, feed efficiency and carcass characteristics were affected (Ellis and Hankins, 1935). Keith and Miller (1939) found that when rations containing up to 18 percent protein were fed that the maximum and most efficient gains were made by pigs on the highest levels of protein. Similarily Abernathy _et al._ (1958) reported significantly faster gains during the first 7 weeks on experiment with pigs fed rations containing 18% protein when compared to those fed rations containing 14% protein. In other experiments (Hoefer _et al._

1952; Tribble et al., 1956) no differences in rate of gain and feed efficiency were obtained between pigs fed rations containing various levels of protein. In general with growing and finishing pigs it has not been found desirable to feed rations containing more than 26% protein which, although not seriously detrimental, are often unpalatable, cause scouring and result in a low rate and efficiency of gain (Robison, 1940; Terrill et al., 1952).

Bowland and Berg (1959) noted that in the growing period to 110 lb., high protein rations (21%) resulted in improved feed efficiency as compared to medium protein (17%) rations. They found further that high protein alone or in combination with high energy rations improved efficiency of feed utilization in the finishing period. Their results indicated that high protein rations resulted in leaner carcasses. The latter effect has similarily been noted by other workers (Ellis and Hankins, 1935; Robison et al., 1952; Tribble et al., 1956; Ashton et al., 1955).

In contrast to these findings Catron et al., (1952) reported that the percent carcass lean was not affected by protein. These workers further observed that protein had no effect on backfat thickness and length of body. In regard to length of body, this work is supported by Bowland and Berg (1959) who found that neither protein nor energy levels in the ration were associated with changes in carcass length.

Abernathy et al. (1958) and Bowland and Berg (1959) have recently reported studies on protein and energy interrelationships in rations for growing swine. Abernathy et al. (1958) found that a highly significant increase in gains with a corresponding higher feed efficiency

resulted when energy levels of rations were increased. Bowland and Berg (1959) reported that rate of liveweight gain tended to be fastest in pigs fed HE-HP rations throughout the growing and finishing period. These workers also indicated that up to 110 lb. pigs on high energy rations ate more than pigs fed rations low in energy, while from 110 lb. to market weight pigs consumed low energy rations at a higher rate than high energy rations. High energy rations improved efficiency of feed utilization during the latter period.

Citing Fredeen (1953), who found carcass characteristics in Yorkshire hogs to vary between sexes, Bowland and Berg (1959) suggested that it is probable that optimum protein to energy ratios in the ration may differ between sexes, at least in relation to ultimate carcass quality. In their study they found male pigs gained more rapidly than females. They also noted that female pigs required less feed per pound gain than male pigs in the finishing period and that carcasses from female pigs excelled those from male pigs in all factors measured except carcass length.

Energy intake may be reduced in two ways; by lowering the energy content of the ration or by restricting the amount of feed which an animal is allowed to consume. It is known that the time required for feed to pass through the gut in pigs may be increased by at least 4 hours by restriction of feed intake (Castle and Castle, 1957). As a consequence of smaller quantities of feed flowing more slowly through the gastro-intestinal tract more absorption occurs. This may be the explanation behind the findings (Berg and Bowland, 1958; Barber et al., 1957; Robison, 1952) that lower levels of feed intake (restricted feeding) resulted in

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

slower but more efficient gains than self-feeding. When the feed intake of pigs is restricted superior carcasses are produced (Berg and Bowland, 1958; McMeekan, 1940). As less available energy is required to produce lean as compared to fat, the leaner carcasses of the pigs fed restricted rations could also be associated with the improved efficiency of feed utilization.

# EXPERIMENTAL

## OBJECTIVES

The major objective of these experiments was to study energy-nitrogen relationships in swine rations. Specific experiments were designed to study: (a) Energy digestibility and nitrogen retention in weanling rats fed rations containing non-nutritive cellulose and finely ground vermiculite as diluents to lower the energy level of the rations. This was a preliminary experiment to test the value of vermiculite in experiments of this type, (b) Energy digestibility and nitrogen retention when 4 rations containing 2 levels of protein and 2 levels of energy were fed to pigs averaging 15, 50 and 110 lb. liveweight, and (c) Rate of gain, efficiency of feed utilization and carcass characteristics of pigs of 4 breeding groups fed these same 4 rations from weaning to market weight.

## METHODS AND PROCEDURES

### A. FORMULATION OF EXPERIMENTAL RATIONS

Energy-nitrogen relationship studies require rations varying in either nitrogen level and/or ADE content. In making these ration changes consideration must be given to the fact that when the ADE content of a ration is increased adjustments must be made to prevent the occurrence of nutritional deficiencies such as minerals and vitamins which may result from a lowered feed intake (Sibbald, 1957).

In order to vary the ADE content of the feed it was decided that a diluent should be used. For this purpose Terralite, a fine aggregate of vermiculite, was selected. The suitability of its use was determined by comparing it with Alphacel, a non-nutritive cellulose,

which has been successfully used in rat studies.

The formulation and composition of the rations are given in Tables 1, 2, 3 and 4.

TABLE I. - RATIONS USED IN ENERGY-PROTEIN EXPERIMENTS

| Ration No. | Ration | | Diluent Used |
|---|---|---|---|
| 1 | High energy-high protein | (HE-HP) | None |
| 2 | Low energy-low Protein | (LE-LP) | Terralite* |
| 3 | Low energy-high protein | (LE-HP) | Terralite* |
| 4 | High energy-low protein | (HE-LP) | None |
| 5 | Low energy-low protein | (LE-LP) | Alphacel** |
| 6 | Low energy-high protein | (LE-HP) | Alphacel** |

* Terralite - Purchased from Insulation Industries (Edmonton) Ltd., 8602 - 106A Ave., Edmonton.
Terralite is a fine aggregate of vermiculite, which is an expanded or exfoliated mica. As analyzed by Vermiculite Institute, 208 S. La Salle Street, Chicago 4, Illinois, the product is relatively inert chemically but has a water holding capacity of 300% of its weight.

** Alphacel - A non-nutritive cellulose prepared by the Nutritional Biochemicals Corportion, Cleveland, Ohio.

Rations fed to hogs are generally altered throughout the growing and finishing period in order to economically meet the nutrient requirements of the animals. This is done by feeding starter, grower and finisher rations which vary in protein and to a lesser extent in energy levels. In this experiment a constant ration was fed for the entire experimental period in order to simplify interpretation of the results.

The experimental rats received the same food as was fed to the pigs - rations 1, 2, 3 and 4. In addition two groups of 4 rats each received low energy diets, 5 and 6, in which Alphacel replaced Terralite as a diluent.

TABLE 2. - FORMULATION AND COMPOSITION OF RATIONS ON AN AIR-DRY BASIS

| Ration No. | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Ingredients | HE-HP | LE-LP | LE-HP | HE-LP | LE-LP | LE-HP |
| Wheat ---------------- | 53.5 | 42.8 | 32.8 | 63.1 | 42.8 | 32.8 |
| Corn ----------------- | 17.0 | 13.6 | 13.6 | 17.0 | 13.6 | 13.6 |
| Sugar ---------------- | 10.0 | 8.0 | 8.0 | 10.0 | 8.0 | 8.0 |
| Soybean oil meal (44%)- | 13.5 | 10.8 | 18.3 | 6.3 | 10.8 | 18.3 |
| Fishmeal (72%) ------- | 4.5 | 3.6 | 6.1 | 2.1 | 3.6 | 6.1 |
| Ground limestone ----- | 0.6 | 0.48 | 0.48 | 0.6 | 0.48 | 0.48 |
| Iodized salt --------- | 0.5 | 0.4 | 0.4 | 0.5 | 0.4 | 0.4 |
| Vitamin mix* --------- | 0.3 | 0.24 | 0.24 | 0.3 | 0.24 | 0.24 |
| Antibiotic supplement** | 0.1 | 0.08 | 0.08 | 0.1 | 0.08 | 0.08 |
| Terralite ------------ | - | 20.0 | 20.0 | - | - | - |
| Alphacel ------------- | - | - | - | - | 20.0 | 20.0 |
| | 100 lb. | 100 lb. | 100 lb. | 100 lb. | 100 lb. | 100 lb. |
| Rations Used in Digestibility Studies | | | | | | |
| Av. crude protein -- % | 18.1 | 14.7 | 17.6 | 13.7 | 14.0 | 17.0 |
| Gross energy - Cal./gm. | 3.93 | 3.25 | 3.25 | 3.91 | 3.94 | 3.99 |
| Moisture ----------- % | 10 | 8 | 8 | 10 | 9 | 9 |
| Experiment 328A | | | | | | |
| Av. crude protein -- % | 17.9 | 14.0 | 17.9 | 13.6 | - | - |
| Calculated Total Digestible Nutrients % | 80.3 | 64.2 | 63.5 | 81.0 | - | - |

* In the HE-HP and HE-LP rations the following levels of vitamins were supplied per 100 lb. of ration.

| | |
|---|---|
| Vitamin A ---------------- | 50,000 I.U. |
| Vitamin $D_2$ ---------------- | 10,000 I.U. |
| Choline ------------------ | 2 gm. |
| Niacin ------------------- | 1.8 gm. |
| Pantothenic acid ---------- | 800 mg. |
| Riboflavin ---------------- | 400 mg. |
| Folic acid ---------------- | 12 mg. |
| Vitamin $B_{12}$ -------------- | 0.9 mg. |

In the LE-LP and LE-HP rations these levels were reduced by 20% on the assumption that these pigs would eat more feed for an equivalent amount of gain.

** The antibiotic supplements supplied 0.5 gm. aureomycin hydrochloride, 0.25 gm. penicillin G procaine and 0.75 gm. streptomycin per 100 lb. or a total of 30 gm. of antibiotic per ton of HE ration.

TABLE 3. - COMPOSITION OF RATIONS ON AN OVEN-DRY BASIS

| Ration No. | 1<br>HE-HP | 2<br>LE-LP | 3<br>LE-HP | 4<br>HE-LP | 5<br>LE-LP | 6<br>LE-HP |
|---|---|---|---|---|---|---|
| Terralite* -------- % | - | 21.7 | 21.7 | - | - | - |
| Alphacel** -------- % | - | - | - | - | 20.9 | 20.9 |
| Average crude protein --------- % | 20.1 | 16.0 | 19.1 | 15.2 | 15.4 | 18.6 |
| Gross energy - Cal./gm. | 4.37 | 3.53 | 3.53 | 4.34 | 4.33 | 4.38 |
| Gross energy less energy from diluent*** ---- Cal./gm. | 4.37 | 3.42 | 3.42 | 4.34 | 3.42 | 3.46 |

* Adding 20% Terralite to the ration decreased the moisture content of the ration by 20 percent. Terralite was therefore considered to be moisture free.

** Adding 20% Alphacel to the ration decreased the moisture content of the ration by 1% - from 10 to 9 percent. Alphacel was considered to contain 5% moisture.

*** The gross energy content of Alphacel was reported to be 420 Cal./100 gm. Bowland et al. 1958, Can. J. Animal Sci. 38: 187-193.

Based on the decrease in energy due to the presence of Terralite in the ration, the gross energy content of Terralite was calculated to be approximately 50 Cal./100 gm.

TABLE 4. - APPARENT DIGESTIBLE ENERGY AND NITROGEN OF OVEN-DRY RATIONS

| Ration | 1 HE-HP | 2 LE-LP | 3 LE-HP | 4 HE-LP | 5 LE-LP | 6 LE-HP |
|---|---|---|---|---|---|---|
| Diluent | None | Terralite | Terralite | None | Alphacel | Alphacel |
| (a) Gross energy Cal./100 gm. feed | 437 | 353 | 353 | 434 | 433 | 438 |
| (b) ADE Cal./100 gm. feed | | | | | | |
| Rats --------- | 383 | 291 | 288 | 379 | 307 | 308 |
| 15 lb. pigs -- | 387 | 294 | 287 | 385 | - | - |
| 50 lb. pigs -- | 377 | 288 | 282 | 364 | - | - |
| 110 lb. pigs - | 387 | 299 | 297 | 385 | - | - |
| Mean for pigs | 384 | 294 | 289 | 378 | - | - |
| (c) Gross nitrogen mg./100 gm. feed | 2892 | 2356 | 2811 | 2189 | 2231 | 2725 |
| (d) ADN mg./100 gm. feed | | | | | | |
| Rats --------- | 2548 | 1875 | 2252 | 1893 | 1874 | 2289 |
| 15 lb. pigs -- | 2565 | 1869 | 2205 | 1889 | - | - |
| 50 lb. pigs -- | 2443 | 1781 | 2145 | 1685 | - | - |
| 110 lb. pigs - | 2546 | 1928 | 2325 | 1907 | - | - |
| Mean for pigs | 2518 | 1859 | 2225 | 1827 | - | - |
| (e) ADE Cal./gm. ADN in feed | | | | | | |
| Rats --------- | 150 | 155 | 128 | 200 | 164 | 135 |
| 15 lb. pigs -- | 151 | 157 | 130 | 204 | - | - |
| 50 lb. pigs -- | 154 | 162 | 131 | 216 | - | - |
| 110 lb. pigs - | 152 | 155 | 128 | 202 | - | - |
| Mean for pigs | 152 | 158 | 130 | 207 | - | - |

Diets containing Alphacel were mixed at the University Animal Science Laboratory. The other rations were ground and mixed at the University Livestock Farm, bagged in approximately 100 lb. lots and stored in a dry heated barn. Diets fed to the rats were further ground through a No. 50 screen in the Weber Pulverizing Mill* to prevent the rats from sorting their food. The rat diets were kept in sealed jars in the rat room of the Animal Science Laboratory.

B. METHODS AND PROCEDURES IN RAT EXPERIMENT

At 21 days of age 24 weanling albino male rats of the Sprague-Dawley strain were obtained from the laboratory stock colony and groups of 6, representing the 6 diets used, were randomly allotted to individual cages in 4 different rows. When possible rats from the same litter were placed in the same row. The metabolism portion of this experiment was conducted between July 31, 1958 and August 11, 1958.

Following the method described by Sibbald (1957) the weanling rats were fed ad libitum the experimental diets to which they had been allotted plus vitamins A and D**. Following a ration acclimatization period of 7 days, the rats were placed in metabolism cages that had been sprayed with a saturated solution of boric acid in 95% ethanol. Food consumption and rat weights were recorded at the time of weaning and at 7 day intervals thereafter, until the end of the trial.

Urine plus cage washings were collected in 25 ml. of 50% concentrated $H_2SO_4$ during the metabolism period and these were filtered into ground glass stoppered flasks and stored at $38^{o}F$. The samples were made up to

---

* Weber Laboratory Pulverizing Mill manufactured by Weber Bros. Metal Works, Chicago, Ill.

**One drop of oil containing approximately 750 I.U. vitamin A and 300 I.U. vitamin D, was administered weekly to each rat.

250 ml. with water and 10 ml. aliquots were analyzed for nitrogen.

Feces were collected daily during the metabolism period, placed in small aluminum dishes and oven dried at 105°C. Prior to analysis the dried feces were ground in a small Wiley* mill using a 20-mesh screen.

The food was analyzed, using a Parr Oxygen Bomb Calorimeter**, to determine the gross energy content of the rations fed to the rats and to the pigs in Experiments 328 and 328A. Caloric values of fecal samples from the rat and swine trials were similarly determined.

Nitrogen analysis of the food and of the feces and urine obtained from the rat and swine trials were conducted by the Kjeldahl-Gunning method using boric acid to retain the ammonia.

C. METHODS AND PROCEDURES IN SWINE EXPERIMENTS.

The swine experiments were sub-divided into two separate trials:

1) Experiment 328 dealt with energy and nitrogen metabolism studies with 16 pigs at 15, 50 and 110 lb. weights. Information pertaining to rate of gain, efficiency of feed utilization and carcass characteristics of these pigs from weaning to market weight was also obtained.

2) Experiment 328A, was conducted with 64 pigs of 4 breeding groups and was designed to give information on rate of gain, efficiency of feed utilization and carcass characteristics. This experiment is being replicated this summer so that no detailed discussion will be given of interactions, particularly those relating to breeding groups.

---

* Wiley Mill No. 4276 sold by A. H. Thomas Co. Philadelphia, U.S.A.

** Parr Instrument Company, Moline, Illinois; temperature changes registered by a Brown Electronik Recorder manufactured by Minneapolis-Honeywell Regulator Company, Philadelphia, Pennsylvania.

1) Experiment 328

a) Allotment

As facilities became available between June 16, 1958 and August 17, 1958, 16 half-sib Landrace-Yorkshire crossbred pigs 3 to 4 weeks of age, averaging 12 pounds in weight, were obtained from a nearby farm for metabolism studies. When possible each group of 4 pigs was from the same litter. The pigs in each group were allotted at random to the 4 rations used in the trial.

General management, metabolism trials and methods of analysis were similar to those reported by Hussar (1958) and are outlined only briefly.

b) General Management

The purchased pigs were ear-notched at birth for identification purposes and had been routinely treated for anemia. They were castrated upon completion of the 15 lb. metabolism trial, and at an average weight of 30 lb. were treated with a cadmium oxide compound for control of ascarids.

For the 15 lb. metabolism period the pigs were transported to the animal rooms at the University Animal Science Research Laboratory. The 50 and 110 lb. metabolism trials were conducted at the University Livestock Farm. Individual feed consumption data were obtained for the pigs. Both while on and off metabolism, they were fed individually for periods of approximately one hour 3 times daily. Between feedings when not on metabolism studies the pigs ran together in an area where they had access to automatic watering bowls.

Pig weights were recorded at weekly intervals, and at the first weekly weighing after a pig exceeded 190 lb. liveweight it was shipped to market. Following slaughter, Canadian Government carcass grades and Advanced Registry (National Bacon Hog Policy, 1954) measurements and scores were obtained.

c) Metabolism and Methods of Analysis

The pigs, prior to being placed on metabolism, were allowed to become accustomed to the ration for a period of at least 10 days, or until they reached approximately 15 lb. in weight. An overnight acclimatization period was also required when the pigs were placed in the metabolism cages in order that the pigs might become accustomed to the feed and watering troughs. Feed consumed during the metabolism period was recorded.

To help prevent scouring and vomiting, pigs were treated with soluble Terramycin before moving them from the University Livestock Farm to the animal rooms at the University Animal Science Laboratory. When these symptoms developed the data collected were discarded and the pigs were returned to the farm for a 2 to 3 day recovery period.

Feces were collected using a harness described by Kolari et al. (1955) and modified by Hussar (1958)*. The feces were collected in polyethylene bags which were removed daily. All fecal material was emptied from the bags and the total feces dried for approximately 12 hours at 105°C.

---

* Details of the metabolism harness as well as of the construction of the waterers, feeders and metabolism cages used for the 15 lb. pigs may be found in Hussar's thesis (1958).

The dried feces were stored in closed glass bottles and upon completion of the experiment the composite samples from each pig were weighed and ground. The initial grinding was through a 2mm. mesh screen in a Wiley No. 1 Mill*. A 100 gm. aliquot was then drawn and passed through a No. 24 screen in a Weber Pulverizing Mill. The resulting sample was sealed in a glass bottle and stored at 38°F until it was analyzed for energy and nitrogen.

Urine was collected in plastic pails containing 50 ml. of 50% $H_2SO_4$. The acidified urine plus cage washings collected during the 5 day period were filtered and weighed. Five ml. aliquots of this filtered urine were then analyzed for nitrogen content. The weight of the 5 ml. aliquot was determined by weighing a 50 ml. aliquot in a volumetric flask.

Metabolism studies on 50 and 110 lb. pigs were conducted at the University Livestock Farm in cages described by Hussar (1958). The pigs were kept on trial for a 5 day period during which time feed intake was recorded and feces and urine samples were collected. No cage acclimatization period was required.

Urine samples were collected in plastic buckets containing 75 ml. of 50% $H_2SO_4$. At the conclusion of the trial the weight of the urine plus washings was determined. The sample was then thoroughly mixed and an aliquot taken for nitrogen analysis as in the 15 lb. pig trial.

Fecal samples were collected 3 times during the 5 day metabolism period. Total feces from each pig was brought to the laboratory, dried, ground and analyzed as in the 15 lb. pig trial.

---

* Wiley No. 1 Mill. Manufactured by A. H. Thomas Co., Philadelphia, Pa.

2) Experiment 328A

An experiment was set up in September, 1958, to study the rate of gain, efficiency of feed utilization and carcass characteristics of 4 strains of pigs of both sexes when fed the rations used in Experiment 328. The pigs, housed in the experimental feeding wing of the hog barn at the University Livestock Farm, were supplied water from automatic waterers and fed ad libitum from weaning to market weight. Feed consumption data were recorded and the pigs were weighed at weekly intervals. Following slaughter, Canadian Government carcass grades and Advanced Registry (National Bacon Hog Policy, 1954) measurements and scores were obtained as in experiment 328.

The plan of the experiment was to allot 64 approximately 20 lb. 6 week old weanling pigs to 16 lots, 4 lots each of:

(a) Yorkshire
(b) Landrace-Yorkshire
(c) Tamworth-Yorkshire, and
(d) Lacombe-Yorkshire pigs.

Each lot contained 2 males and 2 females. The 4 lots of each strain were alloted at random to rations 1 to 4 as shown in Table 2.

The pigs were ear-notched and had been routinely treated for anemia prior to being placed on test. They were later treated for the removal of ascarids, and the males were castrated at a similar age to the pigs in Experiment 328.

## RESULTS AND DISCUSSIONS

A summary of the results obtained in the rat and swine trials and mean squares obtained by analysis of variance of individual data are given in Tables 4 to 26. The methods of analyses in these tables followed those outlined by Goulden (1956).

In Table 4, ADE and ADN contents of the rations fed to rats and swine are given. Tables 5A to 7B deal with the rat metabolism trial, 8A to 16 with the swine metabolism trials and 17 to 26 with average daily gain, rate of gain, efficiency of feed utilization and carcass characteristics of swine in the group feeding experiment.

### A. ENERGY DIGESTIBILITY AND NITROGEN RETENTION TRIAL WITH RATS

#### 1) Average Body Weight, Rate of Gain, Food Consumption and Efficiency of Food Utilization

The data for average body weight, rate of gain, food consumption and efficiency of food utilization for the rats on metabolism studies are given in Tables 5A and B with the statistical analyses data in Tables 6A and B and 7A and B.

The average weight of the rats on each diet at the beginning of the acclimatization period was 36 ± 1 gram. Rats on low protein and Terralite diets during acclimatization made slow weight gains and therefore weighed less than the other rats while on metabolism. A similar diet effect has been reported by Bowland *et al.* (1958) who noted that rats receiving low nitrogen diets gained more slowly during the 7-day acclimatization period than those receiving higher levels of nitrogen. Sibbald (1957) also noted a significant difference between rat weights following acclimatization, the difference being primarily a function of the superior growth promoting effect of diets containing smaller quantities of diluent.

TABLE 5A. - RAT METABOLISM TRIAL - BODY WEIGHTS AND FOOD[1] CONSUMPTION

| | Row | Gain in Wt. Acclim. period | Gain in Wt. Metab. period | Av. body wt. met. period | Per 100 gm. Body Weight: Av. weekly gain | Per 100 gm. Body Weight: OD food cons. | Per 100 gm. Body Weight: ADE cons. | Per 100 gm. Body Weight: Gross N cons. | OD food/gm. gain metab. period |
|---|---|---|---|---|---|---|---|---|---|
| | | gm. | gm. | gm. | gm. | gm. | Cal. | mg. | gm. |
| Diet 1 | 1 | 39 | 46 | 101 | 46 | 91 | 349 | 2907 | 2.0 |
| HE-HP | 2 | 34 | 31 | 86 | 36 | 84 | 316 | 2695 | 2.4 |
| | 3 | 28 | 40 | 78 | 52 | 102 | 395 | 3289 | 2.0 |
| | 4 | 32 | 40 | 88 | 45 | 102 | 394 | 3284 | 2.2 |
| Mean | | 33 | 39 | 88 | 45 | 95 | 363 | 3044 | 2.2 |
| Diet 4 | 1 | 23 | 32 | 75 | 43 | 106 | 403 | 2583 | 2.4 |
| HE-LP | 2 | 25 | 34 | 78 | 44 | 105 | 394 | 2552 | 2.4 |
| | 3 | 24 | 34 | 73 | 46 | 116 | 438 | 2820 | 2.5 |
| | 4 | 24 | 35 | 83 | 42 | 108 | 418 | 2635 | 2.6 |
| Mean | | 24 | 34 | 77 | 44 | 109 | 413 | 2648 | 2.5 |
| Diet 2 | 1 | 13 | 34 | 69 | 50 | 128 | 372 | 3293 | 2.6 |
| LE-LP | 2 | 16 | 37 | 71 | 52 | 132 | 369 | 3376 | 2.5 |
| "Terralite" | 3 | 24 | 26 | 70 | 37 | 112 | 338 | 2882 | 3.0 |
| | 4 | 27 | 13 | 72 | 18 | 101 | 294 | 2571 | 5.5 |
| Mean | | 20 | 28 | 70 | 39 | 118 | 343 | 3031 | 3.4 |
| Diet 5 | 1 | 31 | 34 | 85 | 40 | 104 | 317 | 2568 | 2.6 |
| LE-LP | 2 | 24 | 38 | 76 | 50 | 122 | 369 | 2991 | 2.4 |
| "Alphacel" | 3 | 34 | 18 | 83 | 22 | 90 | 274 | 2205 | 4.1 |
| | 4 | 24 | 38 | 74 | 52 | 129 | 403 | 3157 | 2.5 |
| Mean | | 28 | 32 | 80 | 41 | 111 | 340 | 2730 | 2.9 |

[1] Oven-dry basis.

[illegible]

TABLE 5A CONT'D. - RAT METABOLISM TRIAL - BODY WEIGHTS AND FOOD[1] CONSUMPTION

| | | Gain in Wt. | | | Per 100 gm. Body Weight | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Row | Acclim. period | Metab. period | Av. body wt. met. period | Av. weekly gain | OD food cons. | ADE cons. | Gross N cons. | OD food/gm. gain metab. period |
| | | gm. | gm. | gm. | gm. | gm. | Cal. | mg. | gm. |
| Diet 3 | 1 | 29 | 38 | 84 | 45 | 124 | 357 | 3794 | 2.8 |
| LE-HP | 2 | 21 | 38 | 76 | 50 | 124 | 356 | 3771 | 2.5 |
| "Terralite" | 3 | 22 | 35 | 74 | 48 | 126 | 367 | 3846 | 2.6 |
| | 4 | 29 | 17 | 77 | 22 | 103 | 294 | 3158 | 4.6 |
| Mean | | 25 | 32 | 78 | 41 | 119 | 344 | 3642 | 3.1 |
| Diet 6 | 1 | 31 | 45 | 86 | 53 | 127 | 381 | 3781 | 2.4 |
| LE-HP | 2 | 28 | 41 | 86 | 48 | 113 | 343 | 3364 | 2.4 |
| "Alphacel" | 3 | 31 | 18 | 74 | 24 | 94 | 394 | 2812 | 4.0 |
| | 4 | 32 | 31 | 85 | 36 | 109 | 345 | 3235 | 3.0 |
| Mean | | 31 | 34 | 83 | 40 | 111 | 341 | 3298 | 2.9 |

[1] Oven-dry basis.

TABLE 5B. - RAT METABOLISM TRIAL - DRY MATTER, ENERGY AND NITROGEN DIGESTIBILITY[2], NITROGEN RETENTION

| | Row | Digestibility | | | Corr.[3] Digestibility | | Retention | |
|---|---|---|---|---|---|---|---|---|
| | | Dry matter | Energy | Nitrogen | Dry matter | Energy | Gross N | ADN |
| | | % | % | % | % | % | % | % |
| Diet 1 | 1 | 86 | 88 | 88 | 86 | 88 | 52 | 59 |
| HE-HP | 2 | 85 | 86 | 88 | 85 | 86 | 49 | 56 |
| | 3 | 87 | 88 | 89 | 87 | 88 | 56 | 63 |
| | 4 | 86 | 88 | 87 | 86 | 88 | 56 | 64 |
| Mean | | 86 | 88 | 88 | 86 | 88 | 53 | 60 |
| Diet 4 | 1 | 87 | 87 | 87 | 87 | 87 | 50 | 57 |
| HE-LP | 2 | 86 | 86 | 84 | 86 | 86 | 52 | 62 |
| | 3 | 87 | 87 | 87 | 87 | 87 | 54 | 62 |
| | 4 | 88 | 89 | 88 | 88 | 89 | 52 | 59 |
| Mean | | 87 | 87 | 86 | 87 | 87 | 52 | 60 |
| Diet 2 | 1 | 63 | 82 | 78 | 82 | 85 | 48 | 61 |
| LE-LP | 2 | 63 | 79 | 77 | 82 | 82 | 45 | 59 |
| "Terralite" | 3 | 70 | 85 | 82 | 89 | 88 | 44[4] | 56[4] |
| | 4 | 68 | 83 | 82 | 87 | 86 | 40 | 49 |
| Mean | | 66 | 82 | 80 | 85 | 85 | 44 | 56 |
| Diet 5 | 1 | 68 | 70 | 84 | 86 | 88 | 51 | 61 |
| LE-LP | 2 | 68 | 70 | 84 | 86 | 88 | 52 | 63 |
| "Alphacel" | 3 | 68 | 71 | 83 | 86 | 88 | 47 | 57 |
| | 4 | 70 | 72 | 85 | 88 | 90 | 52 | 62 |
| Mean | | 69 | 71 | 84 | 87 | 88 | 51 | 61 |
| Diet 3 | 1 | 60 | 81 | 76 | 79 | 84 | 43 | 57 |
| LE-HP | 2 | 64 | 82 | 82 | 83 | 84 | 43 | 53 |
| "Terralite" | 3 | 64 | 83 | 81 | 83 | 85 | 42 | 52 |
| | 4 | 64 | 80 | 82 | 82 | 83 | 36 | 44 |
| Mean | | 63 | 82 | 80 | 82 | 84 | 41 | 52 |
| Diet 6 | 1 | 66 | 68 | 85 | 84 | 86 | 45 | 53 |
| LE-HP | 2 | 67 | 69 | 82 | 85 | 87 | 42 | 51 |
| "Alphacel" | 3 | 67 | 71 | 84 | 85 | 89 | 37 | 44 |
| | 4 | 68 | 72 | 85 | 86 | 90 | 38 | 45 |
| Mean | | 67 | 70 | 84 | 85 | 88 | 40 | 48 |

[2] Oven-dry basis.

[3] In correcting the digestibility figures the effect which the diluent had upon the previous calculation was removed.

[4] Missing value obtained by the method of Goulden, pages 318-320.

TABLE 6A. - RAT METABOLISM TRIAL - ROW, DIET, DILUENT AND PROTEIN MEANS AND L.S.D.'s FOR TABLE 5A

| | Gain in Wt. | | Av. body wt. | Per 100 gm. Body Wt. | | | | OD food/gm. gain |
|---|---|---|---|---|---|---|---|---|
| | Acclim. period | Metab. period | Metab. period | Av. weekly gain | OD food cons. | ADE cons. | Gross N cons | Metab. period |
| | gm. | gm. | gm. | gm. | gm. | Cal. | mg. | gm. |
| Row 1 | 28 | 38 | 83 | 46 | 113 | 363 | 3154 | 2.5 |
| Row 2 | 25 | 36 | 79 | 47 | 113 | 358 | 3125 | 2.4 |
| Row 3 | 27 | 28 | 75 | 38 | 107 | 351 | 2976 | 3.0 |
| Row 4 | 28 | 29 | 80 | 36 | 109 | 358 | 3007 | 3.4 |
| Row L.S.D. | - | - | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| HE-HP Diet 1 | 33 | 39 | 88 | 45 | 95 | 363 | 3044 | 2.2 |
| HE-LP Diet 4 | 24 | 34 | 77 | 44 | 109 | 413 | 2648 | 2.5 |
| LE-LP Diet 2 | 20 | 28 | 70 | 39 | 118 | 343 | 3031 | 3.4 |
| LE-LP Diet 5 | 28 | 32 | 80 | 41 | 111 | 340 | 2730 | 2.9 |
| LE-HP Diet 3 | 25 | 32 | 78 | 41 | 119 | 344 | 3642 | 3.1 |
| LE-HP Diet 6 | 31 | 34 | 83 | 40 | 111 | 341 | 3298 | 2.9 |
| Diet L.S.D. | - | - | 7.7 | n.s. | n.s. | n.s. | 540 | n.s. |
| No diluent HE Diets 1 and 4 | 28 | 36 | 83 | 44 | 102 | 388 | 2846 | 2.4 |
| Terralite LE Diets 2 and 3 | 22 | 30 | 74 | 40 | 118 | 344 | 3336 | 3.2 |
| Alphacel LE Diets 5 and 6 | 30 | 33 | 81 | 40 | 111 | 340 | 3014 | 2.9 |
| Diluent L.S.D. | - | - | 5.5 | n.s. | n.s. | n.s. | 382 | n.s. |
| High protein Diet 1, 3 and 6 | 30 | 35 | 83 | 42 | 108 | 349 | 3328 | 2.7 |
| Low protein Diet 4, 2 and 5 | 24 | 31 | 76 | 41 | 113 | 366 | 2803 | 2.9 |

L.S.D. - Least significant difference
n.s. - No significant difference - as determined in Table 7A
\- - Not calculated

TABLE 6B. - RAT METABOLISM TRIAL - ROW, DIET, DILUENT AND PROTEIN MEANS AND L.S.D.'s FOR TABLE 5B

| | | Digestibility | | | Corr. Digestibility | | Retention | |
|---|---|---|---|---|---|---|---|---|
| | | Dry matter | Energy | Nitrogen | Dry matter | Energy | Gross N | ADN |
| | | % | % | % | % | % | % | % |
| Row 1 | | 72 | 79 | 83 | 84 | 86 | 48 | 58 |
| Row 2 | | 72 | 79 | 83 | 84 | 86 | 47 | 57 |
| Row 3 | | 74 | 81 | 84 | 86 | 88 | 47 | 56 |
| Row 4 | | 74 | 81 | 85 | 86 | 88 | 46 | 54 |
| Row L.S.D. | | - | - | n.s. | 1.9 | 1.4 | n.s. | n.s. |
| HE-HP | Diet 1 | 86 | 88 | 88 | 86 | 88 | 53 | 60 |
| HE-LP | Diet 4 | 87 | 87 | 86 | 87 | 87 | 52 | 60 |
| LE-LP | Diet 2 | 66 | 82 | 80 | 85 | 85 | 44 | 56 |
| LE-LP | Diet 5 | 69 | 71 | 84 | 87 | 88 | 51 | 61 |
| LE-HP | Diet 3 | 63 | 82 | 80 | 82 | 84 | 41 | 52 |
| LE-HP | Diet 6 | 67 | 70 | 84 | 85 | 88 | 40 | 48 |
| | Diet L.S.D. | - | - | 2.9 | 2.4 | 1.8 | 5.0 | 6.4 |
| No diluent HE | Diets 1 and 4 | 86 | 88 | 87 | 86 | 88 | 52 | 60 |
| Terralite LE | Diets 2 and 3 | 64 | 82 | 80 | 84 | 84 | 42 | 54 |
| Alphacel LE | Diets 5 and 6 | 68 | 70 | 84 | 86 | 88 | 46 | 54 |
| Diluent L.S.D. | | - | - | 2.0 | 1.7 | 1.3 | 3.6 | 4.5 |
| High protein | Diets 1, 3 and 6 | 72 | 80 | 84 | 84 | 87 | 45 | 53 |
| Low protein | Diets 4, 2 and 5 | 74 | 80 | 83 | 86 | 87 | 49 | 59 |

L.S.D. - Least significant difference
n.s. - No significant difference - as determined in Table 7A
\- - Not calculated

TABLE 7A. - RAT METABOLISM TRIAL - MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF TABLE 5A

| | | | Per 100 gm. Body Wt. | | | | |
|---|---|---|---|---|---|---|---|
| | DF | Av. body wt. met. period | Av. weekly gain | OD food cons. | ADE cons. | Gross N cons. | OD food/gm. gain |
| Total | 23 | | | | | | |
| Diet | 5 | 148** | 17 | 311 | 3274 | 540,519* | 0.8 |
| Row | 3 | 62 | 177 | 68 | 147 | 45,863 | 1.3 |
| Error | 15 | 26 | 125 | 171 | 1724 | 128,687 | 0.6 |
| Diluent | 2 | 177** | 37 | 580 | 5693 | 497,457* | 1.8 |
| Protein | 1 | 321** | 2 | 122 | 1607 | 1,655,132** | 0.2 |
| Interaction | 2 | 32 | 4 | 136 | 1689 | 26,274 | 0.1 |

TABLE 7B. - RAT METABOLISM TRIAL - MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF TABLE 5B

| | | Digestibility | Corr. Digestibility | | | Retention | |
|---|---|---|---|---|---|---|---|
| | DF | Nitrogen | Dry matter | Energy | DF[1] | Gross N | ADN |
| Total | 23 | | | | 22 | | |
| Diet | 5 | 46** | 14** | 12** | 5 | 130** | 111** |
| Row | 3 | 7 | 10* | 6* | 3 | 5 | 20 |
| Error | 15 | 4 | 2 | 1 | 14 | 11 | 18 |
| Diluent | 2 | 113* | 23** | 29** | 2 | 207** | 101* |
| Protein | 1 | 3 | 21* | 1 | 1 | 100** | 191** |
| Interaction | 2 | 1 | 3 | 1 | 2 | 69* | 82* |

* Significant at $P < 0.05$
** Significant at $P < 0.01$

[1] One degree of freedom was lost as a result of the missing value.

To adjust for the weight differences, average weekly gain as well as food, ADE and gross nitrogen consumption during the metabolism period were compared on a 100 gm. body weight basis. Neither the diluent nor protein level significantly influenced any of these factors other than gross nitrogen consumption. However, as suggested by Sibbald (1957), fiber did tend to depress ADE consumption. Low energy diets also appeared to decrease rate of gain.

The nitrogen level had a slight but not significant influence on energy consumption as rats on HE-LP diets consumed a higher level of ADE than those fed on other diets. As explained by Bowland et al. (1958), who obtained similar results this may have represented "an apparent attempt by the rat to get additional nitrogen".

Although the difference was not significant, diets containing diluents (low energy diets) were utilized less efficiently than higher energy diets. Nitrogen levels did not affect efficiency of food utilization.

2) Digestibility of Dry Matter and Energy

Dry matter and energy digestibility figures, as presented in Table 5B, were corrected for moisture content and the presence of a diluent.

Dry matter and energy digestibility remained the same in the presence of Alphacel as on the control diets but decreased in the presence of Terralite. Dry matter digestibility was also lower in rations high in protein.

The coefficients of digestibility for dry matter and energy were significantly higher for rats in the 2 bottom rows of the metabolism rack

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

as compared with rats in the 2 top rows. As the temperature of the top row was only 0.4$^{\circ}$C higher than that of the bottom row and as other factors were apparently equal, the differences in digestibility were likely associated with between litter variation.

3) Consumption and Digestibility of Nitrogen

The data for nitrogen consumption are in Table 5A while the data for nitrogen digestibility and retention are in Table 5B.

As expected, rats fed diets high in protein consumed the greatest amount of nitrogen. A significant difference in gross nitrogen consumption between diluents also resulted as rats fed the Terralite diets consumed more nitrogen than those fed the control diets while rats fed Alphacel and control diets did not differ significantly in nitrogen consumption.

Forbes *et al*. (1958) found the true digestibility of peanut and egg protein and casein was not affected by protein concentration in the diet. Bowland *et al*. (1958), reporting on the influence of dietary fat, found that the percentage ADN increased as nitrogen levels in the diet increased. In this experiment the percentage ADN was not significantly influenced by the level of protein in the diet, however the percentage ADN tended to be higher for diets high in protein.

A significant decrease in percentage ADN occurred when a diluent was used to lower the ADE content of the ration. This is in agreement with work by Meyer (1956) who observed that an increase in the indigestible portion of a diet increased the total fecal nitrogen excretion, and work by Sibbald (1957) who noted that increasing levels of Alphacel tended to decrease the digestibility of the gross nitrogen of the food.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Other workers (Whiting and Bezeau, 1957) have similarily reported decreased protein digestibility in the pig as well as a corresponding increase in the metabolic fecal nitrogen when the fiber content of the ration was increased. In this experiment M.F.N. was not studied but, as reported by Bowland et al. (1958), it is possible that the increase in fiber intake on low energy rations may have increased M.F.N. and hence decreased apparent digestibility of nitrogen.

The significant difference noted in nitrogen digestibility between low energy rations containing Alphacel and those containing Terralite might be accounted for if it is assumed that Terralite increased M.F.N. to a greater degree than Alphacel.

4) Nitrogen Retention

Diets used in this trial had an energy-nitrogen ratio below 277 Cal. ADE per gm. ADN reported by Sibbald et al. (1957) as being optimal for maximum nitrogen utilization. As a result nitrogen retention as a percentage of gross digestible nitrogen was probably low on all diets. A significant difference between the high and low protein diets, however, indicated that nitrogen was used less efficiently as the protein level was increased.

Retention of nitrogen as a percentage of gross nitrogen was also significantly lower on low energy or diluted diets when compared to the higher energy diets, and on diets containing Terralite when compared to those containing Alphacel. This difference can be accounted for if one assumes that an increase in M.F.N., as discussed previously, resulted because of the addition of diluents to the ration.

From the nitrogen retention results it is difficult to determine

what dietary effects caused the significant interaction between diluent and protein, but it probably was associated with diet 5, the LE-LP Alphacel diet, where retention was not lowered in comparison with the high energy diets. No other interactions of significance appeared in this study.

B. ENERGY DIGESTIBILITY AND NITROGEN RETENTION TRIALS WITH SWINE

1) Average Body Weight, Rate of Gain and ADE Consumption

The data for this portion of the swine metabolism studies are reported in Tables 8A for 15 lb. pigs, 11A for 50 lb. pigs and 14A for 110 lb. pigs with analyses data in Tables 9, 12 and 15 respectively.

An attempt was made to put the pigs in each ration on trial at the same weight. However, average body weight during the metabolism period was often higher for the faster growing pigs fed rations high in energy and protein. To adjust for the weight differences, average 5 day gain, ADE and gross nitrogen consumption were compared on a 100 gm. body weight basis.

Average 5 day gain per 100 gm. body weight was not significantly affected by the energy or protein content of the ration, although it was generally higher for pigs on high energy and high protein rations.

ADE consumption was higher for 15 and 50 lb. pigs fed rations high in energy than it was when low energy rations were fed. In the 50 lb. trial this difference was significant. However, in the 110 lb. trial ADE consumption was similar for rations at the different energy levels.

TABLE 8A. - 15 LB. PIG METABOLISM TRIAL - BODY WEIGHTS AND FEED[1] CONSUMPTION

| | | Gain in Wt. | | Av. Body Wt. | | Per 100 gm. Body Wt. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Rep. | Met. period | | Met. period | | Av. 5 day gain | Feed cons. | ADE cons. | Gross N cons. |
| | | lb. | kg. | lb. | kg. | gm. | gm. | Cal. | mg. |
| Ration 1 | 1 | 2.1 | 1.0 | 20.2 | 9.2 | 10.4 | 22.0 | 96.0 | 634.6 |
| HE-HP | 2 | 1.8 | 0.8 | 20.0 | 9.1 | 9.0 | 19.8 | 86.4 | 571.4 |
| | 3 | 2.9 | 1.3 | 22.2 | 10.1 | 13.1 | 17.9 | 78.0 | 516.2 |
| | 4 | 3.6 | 1.6 | 19.8 | 9.0 | 18.2 | 27.4 | 119.9 | 793.0 |
| Mean | | 2.6 | 1.2 | 20.6 | 9.3 | 12.7 | 21.8 | 95.1 | 628.8 |
| Ration 2 | 1 | 2.9 | 1.3 | 17.0 | 7.7 | 17.1 | 23.8 | 83.8 | 560.5 |
| LE-LP | 2 | 1.3 | 0.6 | 16.2 | 7.4 | 8.0 | 22.3 | 78.8 | 526.8 |
| | 3 | 1.8 | 0.8 | 18.0 | 8.2 | 10.0 | 25.6 | 90.4 | 604.2 |
| | 4 | 2.0 | 0.9 | 17.1 | 7.8 | 11.7 | 21.2 | 74.9 | 500.6 |
| Mean | | 2.0 | 0.9 | 17.1 | 7.7 | 11.7 | 23.2 | 82.0 | 548.0 |
| Ration 3 | 1 | 2.8 | 1.3 | 16.0 | 7.3 | 17.5 | 23.7 | 83.8 | 667.1 |
| LE-HP | 2 | 1.4 | 0.6 | 17.7 | 8.0 | 8.0 | 20.6 | 72.9 | 580.3 |
| | 3 | 2.5 | 1.1 | 18.4 | 8.4 | 13.5 | 28.2 | 99.6 | 793.3 |
| | 4 | 2.4 | 1.1 | 16.8 | 7.6 | 14.3 | 25.6 | 90.4 | 719.4 |
| Mean | | 2.3 | 1.0 | 17.2 | 7.8 | 13.3 | 24.6 | 86.7 | 690.0 |
| Ration 4 | 1 | 1.3 | 0.6 | 13.6 | 6.2 | 9.6 | 24.1 | 104.5 | 527.1 |
| HE-LP | 2 | 1.7 | 0.8 | 18.4 | 8.4 | 9.2 | 19.9 | 86.5 | 436.7 |
| | 3 | 2.7 | 1.2 | 19.6 | 8.9 | 13.7 | 23.3 | 101.2 | 510.5 |
| | 4 | 1.2 | 0.5 | 20.6 | 9.3 | 5.8 | 21.2 | 92.2 | 465.2 |
| Mean | | 1.7 | 0.8 | 18.0 | 8.2 | 9.6 | 22.1 | 96.1 | 484.9 |

[1] Oven-dry basis.

TABLE 8B. - 15 LB. PIG METABOLISM TRIAL - DRY MATTER, ENERGY AND NITROGEN DIGESTIBILITY[2]; NITROGEN RETENTION

| | | Digestibility | | | Corr.[3] Digestibility | | Retention | |
|---|---|---|---|---|---|---|---|---|
| | Rep. | Dry matter | Energy | Nitrogen | Dry matter | Energy | Gross N | ADN |
| | | % | % | % | % | % | % | % |
| Ration 1 | 1 | 88 | 87 | 86 | 88 | 87 | 55 | 64 |
| HE-HP | 2 | 91 | 90 | 90 | 91 | 90 | 56 | 62 |
| | 3 | 89 | 88 | 88 | 89 | 88 | 51 | 58 |
| | 4 | 90 | 89 | 90 | 90 | 89 | 57 | 63 |
| Mean | | 89 | 88 | 89 | 89 | 88 | 55 | 62 |
| Ration 2 | 1 | 65 | 78 | 74 | 85 | 82 | 42 | 57 |
| LE-LP | 2 | 73 | 84 | 82 | 93 | 88 | 53 | 65 |
| | 3 | 70 | 83 | 78 | 89 | 87 | 48 | 62 |
| | 4 | 74 | 87 | 84 | 93 | 91 | 52 | 62 |
| Mean | | 70 | 83 | 79 | 90 | 87 | 49 | 62 |
| Ration 3 | 1 | 60 | 79 | 76 | 80 | 83 | 49 | 64 |
| LE-HP | 2 | 70 | 81 | 79 | 89 | 85 | 51 | 65 |
| | 3 | 69 | 82 | 81 | 88 | 86 | 51 | 63 |
| | 4 | 70 | 82 | 78 | 89 | 86 | 50 | 64 |
| Mean | | 67 | 81 | 78 | 87 | 85 | 50 | 64 |
| Ration 4 | 1 | 89 | 88 | 85 | 89 | 88 | 47 | 55 |
| HE-LP | 2 | 89 | 89 | 85 | 89 | 89 | 40 | 47 |
| | 3 | 90 | 89 | 87 | 90 | 89 | 43 | 50 |
| | 4 | 90 | 89 | 88 | 90 | 89 | 36 | 42 |
| Mean | | 90 | 89 | 86 | 90 | 89 | 42 | 48 |

[2]Oven-dry basis.

[3]In correcting the digestibility figures the effect which the diluent had upon the previous calculation was removed.

TABLE 9. - 15 LB. PIG METABOLISM TRIAL - REPLICATE, RATION, ENERGY AND PROTEIN MEANS FOR TABLES 8A AND 8B

| | | Per 100 gm. Body Wt. | | | | Corr. Digestibility | | Retention | |
|---|---|---|---|---|---|---|---|---|---|
| | Av. body wt. met. period | Av. 5 day gain | ADE cons. | Gross N cons. | Nitrogen digest-ibility | Dry matter | Energy | Gross N | ADN |
| | kg. | gm. | Cal. | mg. | % | % | % | % | % |
| Replicate 1 | 7.6 | 13.6 | 92.0 | 597.3 | 80 | 85 | 85 | 48 | 60 |
| Replicate 2 | 8.2 | 8.6 | 81.2 | 528.8 | 84 | 90 | 88 | 50 | 60 |
| Replicate 3 | 8.9 | 12.6 | 92.3 | 606.0 | 84 | 89 | 88 | 48 | 58 |
| Replicate 4 | 8.4 | 12.5 | 94.3 | 619.5 | 85 | 91 | 89 | 49 | 58 |
| HE-HP Ration 1 | 9.3 | 12.7 | 95.1 | 628.8 | 89 | 89 | 88 | 55 | 62 |
| LE-LP Ration 2 | 7.7 | 11.7 | 82.0 | 548.0 | 79 | 90 | 87 | 49 | 62 |
| LE-HP Ration 3 | 7.8 | 13.3 | 86.7 | 690.0 | 78 | 87 | 85 | 50 | 64 |
| HE-LP Ration 4 | 8.2 | 9.6 | 96.1 | 484.9 | 86 | 90 | 89 | 42 | 48 |
| High energy rations 1 and 4 | 8.8 | 11.1 | 95.6 | 556.8 | 87 | 90 | 89 | 48 | 55 |
| Low energy rations 2 and 3 | 7.8 | 12.5 | 84.3 | 619.0 | 79 | 88 | 86 | 50 | 63 |
| High protein rations 1 and 3 | 8.6 | 13.0 | 90.9 | 659.4 | 84 | 88 | 87 | 52 | 63 |
| Low protein rations 2 and 4 | 8.0 | 10.6 | 89.0 | 516.4 | 83 | 90 | 88 | 45 | 55 |

TABLE 10 - 15 LB. PIG METABOLISM TRIAL - MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF TABLES 8A AND 8B

| | | Av. body | Per 100 gm. body wt. | | | Digestibility | | | Retention | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DF | wt. met. period | Av. 5 day gain | A D E cons | Gross N cons | Corr. Dry Matter | Corr Energy | Nitrogen | Gross N | A D N |
| Total | 15 | | | | | | | | | |
| Ration | 3 | 2.1* | 10.7 | 184.6 | 32,404.2* | 9.9 | 12.4* | 103.1** | 116.2* | 200.3** |
| Replicate | 3 | 1.2 | 19.9 | 141.9 | 6,552.9 | 25.7* | 11.1* | 14.8 | 3.4 | 4.9 |
| Error | 9 | 0.5 | 12.6 | 141.6 | 6,510.1 | 4.6 | 2.2 | 4.4 | 16.8 | 15.7 |
| Energy | 1 | 3.8* | 7.9 | 507.3 | 15,457.3 | 7.2 | 29.6** | 296.0** | 6.6 | 235.0** |
| Protein | 1 | 1.4 | 22.0 | 13.7 | 81,751.7** | 12.4 | 4.7 | 2.3 | 203.1** | 247.0** |
| Interaction | 1 | 1.1 | 2.3 | 32.7 | 3.7 | 10.2 | 2.9 | 11.0 | 138.7* | 119.0* |

* Significant at $P < 0.05$
** Significant at $P < 0.01$

TABLE 11A - 50 LB. PIG METABOLISM TRIAL - BODY WEIGHTS AND FEED CONSUMPTION

| | | Gain in wt. | | Av. body wt. | | Per 100 gm. Body Wt. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Rep. | Met. period | | Met. period | | Av. 5 day gain | Feed cons | A D E cons | Gross N cons |
| | | lb. | kg. | lb. | kg. | gm. | gm. | Cal. | mg. |
| Ration 1 | 1 | 4.5 | 2.0 | 54.8 | 24.9 | 8.2 | 23.0 | 100.6 | 665.0 |
| HE-HP | 2 | 6.5 | 3.0 | 56.8 | 25.8 | 11.4 | 23.8 | 104.0 | 687.8 |
| | 3 | 5.5 | 2.5 | 47.8 | 21.7 | 11.5 | 26.8 | 117.0 | 773.6 |
| | 4 | 7.0 | 3.2 | 47.0 | 21.3 | 14.9 | 29.5 | 129.0 | 853.1 |
| Mean | | 5.9 | 2.7 | 51.6 | 23.4 | 11.5 | 25.8 | 112.6 | 744.9 |
| Ration 2 | 1 | 4.0 | 1.8 | 45.5 | 20.6 | 8.8 | 28.3 | 100.0 | 668.6 |
| LE-LP | 2 | 5.2 | 2.4 | 47.1 | 21.4 | 11.0 | 28.4 | 100.1 | 669.1 |
| | 3 | 0.5 | 0.2 | 38.2 | 17.3 | 1.3 | 28.4 | 100.4 | 671.2 |
| | 4 | 2.0 | 0.9 | 40.0 | 18.1 | 5.0 | 28.1 | 99.2 | 662.9 |
| Mean | | 2.9 | 1.3 | 42.7 | 19.4 | 6.5 | 28.3 | 99.9 | 667.9 |
| Ration 3 | 1 | 5.0 | 2.3 | 44.5 | 20.2 | 11.2 | 26.9 | 95.0 | 756.2 |
| LE-HP | 2 | 5.0 | 2.3 | 48.0 | 21.8 | 10.4 | 26.9 | 94.8 | 754.8 |
| | 3 | 5.0 | 2.3 | 41.0 | 18.6 | 12.2 | 32.3 | 114.2 | 908.8 |
| | 4 | 4.0 | 1.8 | 46.5 | 21.1 | 8.6 | 28.7 | 101.3 | 806.5 |
| Mean | | 4.8 | 2.2 | 45.0 | 20.4 | 10.6 | 28.7 | 101.3 | 806.5 |
| Ration 4 | 1 | 6.0 | 2.7 | 45.5 | 20.6 | 13.2 | 28.9 | 125.4 | 632.9 |
| HE-LP | 2 | 6.2 | 2.8 | 53.8 | 24.4 | 11.5 | 29.3 | 127.2 | 641.7 |
| | 3 | 3.5 | 1.6 | 40.2 | 18.2 | 8.7 | 30.5 | 132.3 | 667.5 |
| | 4 | 5.0 | 2.3 | 40.5 | 18.4 | 12.4 | 33.4 | 144.8 | 730.6 |
| Mean | | 5.2 | 2.4 | 45.0 | 20.4 | 11.4 | 30.5 | 132.4 | 668.2 |

[illegible]

TABLE 11B. - 50 LB. PIG METABOLISM TRIAL - DRY MATTER, ENERGY AND NITROGEN DIGESTIBILITY; NITROGEN RETENTION

| | | Digestibility | | | Corr. Digestibility | | Retention | |
|---|---|---|---|---|---|---|---|---|
| | Rep. | Dry matter | Energy | Nitrogen | Dry matter | Energy | Gross N | ADN |
| | | % | % | % | % | % | % | % |
| Ration 1 | 1 | 88 | 87 | 86 | 88 | 87 | 44 | 51 |
| HE-HP | 2 | 87 | 87 | 86 | 87 | 87 | 48 | 56 |
| | 3 | 87 | 86 | 84 | 87 | 86 | 48 | 58 |
| | 4 | 86 | 85 | 81 | 86 | 85 | 51 | 62 |
| Mean | | 87 | 86 | 84 | 87 | 86 | 48 | 57 |
| Ration 2 | 1 | 69 | 83 | 79 | 88 | 86 | 55 | 70 |
| LE-LP | 2 | 67 | 82 | 78 | 86 | 86 | 62 | 80 |
| | 3 | 64 | 80 | 71 | 83 | 83 | 47 | 66 |
| | 4 | 65 | 81 | 74 | 84 | 85 | 48 | 65 |
| Mean | | 66 | 82 | 76 | 85 | 85 | 53 | 70 |
| Ration 3 | 1 | 71 | 84 | 82 | 90 | 87 | 54 | 66 |
| LE-HP | 2 | 69 | 80 | 76 | 88 | 83 | 53 | 69 |
| | 3 | 65 | 75 | 72 | 84 | 78 | 49 | 68 |
| | 4 | 67 | 80 | 75 | 86 | 84 | 39 | 52 |
| Mean | | 68 | 80 | 76 | 87 | 83 | 49 | 64 |
| Ration 4 | 1 | 84 | 85 | 78 | 84 | 85 | 55 | 70 |
| HE-LP | 2 | 85 | 85 | 79 | 85 | 85 | 50 | 63 |
| | 3 | 83 | 83 | 75 | 83 | 83 | 44 | 58 |
| | 4 | 84 | 83 | 75 | 84 | 83 | 37 | 49 |
| Mean | | 84 | 84 | 77 | 84 | 84 | 46 | 60 |

[illegible]

[illegible]

TABLE 12. - 50 LB. PIG METABOLISM TRIAL - REPLICATE, RATION, ENERGY AND PROTEIN MEANS FOR TABLES 11A AND 11B

| | | Per 100 gm. Body Wt. | | | Nitrogen | Corr. Digestibility | | Retention | |
|---|---|---|---|---|---|---|---|---|---|
| | Av. body wt. met. period | Av. 5 day gain | ADE cons. | Gross N cons. | digest-ibility | Dry matter | Energy | Gross N | ADN |
| | kg. | gm. | Cal. | mg. | % | % | % | % | % |
| Replicate 1 | 21.6 | 10.4 | 105.2 | 680.7 | 81 | 88 | 86 | 52 | 64 |
| Replicate 2 | 23.3 | 11.1 | 106.5 | 688.3 | 80 | 87 | 85 | 53 | 67 |
| Replicate 3 | 19.0 | 8.4 | 116.0 | 755.3 | 76 | 84 | 83 | 47 | 62 |
| Replicate 4 | 19.7 | 10.2 | 118.6 | 763.3 | 76 | 85 | 84 | 44 | 57 |
| HE-HP Ration 1 | 23.4 | 11.5 | 112.6 | 744.9 | 84 | 87 | 86 | 48 | 57 |
| LE-LP Ration 2 | 19.4 | 6.5 | 99.9 | 667.9 | 76 | 85 | 85 | 53 | 70 |
| LE-HP Ration 3 | 20.4 | 10.6 | 101.3 | 806.5 | 76 | 87 | 83 | 49 | 64 |
| HE-LP Ration 4 | 20.4 | 11.4 | 132.4 | 668.2 | 77 | 84 | 84 | 46 | 60 |
| High energy rations 1 and 4 | 21.9 | 11.5 | 122.5 | 706.5 | 81 | 86 | 85 | 47 | 58 |
| Low energy rations 2 and 3 | 19.9 | 8.6 | 100.6 | 737.2 | 76 | 86 | 84 | 51 | 67 |
| High protein rations 1 and 3 | 21.9 | 11.1 | 107.0 | 775.7 | 80 | 87 | 85 | 48 | 60 |
| Low protein rations 2 and 4 | 19.9 | 9.0 | 116.2 | 668.0 | 76 | 85 | 84 | 50 | 65 |

TABLE 13. - 50 LB. PIG METABOLISM TRIAL - MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF TABLES 11A AND 11B

| | | | Per 100 gm. Body Wt. | | | Digestibility | | | Retention | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DF | Av. body wt. met. period | Av. 5 day gain | ADE cons. | Gross N cons. | Corr. dry matter | Corr. energy | Nitrogen | Gross N | ADN |
| Total | 15 | | | | | | | | | |
| Ration | 3 | 12.1** | 22.3 | 902.2** | 17,989.3** | 7.2* | 6.7 | 68.3** | 35.6 | 133.9 |
| Replicate | 3 | 15.3** | 5.1 | 178.2 | 7,537.2 | 11.0** | 10.4* | 29.5** | 82.4 | 72.0 |
| Error | 9 | 1.2 | 8.9 | 50.0 | 2,346.1 | 1.5 | 2.4 | 2.8 | 27.0 | 45.2 |
| Energy | 1 | 16.3** | 33.7 | 1,920.2** | 3,771.5 | .7 | 3.9 | 91.6** | 61.4 | 302.0* |
| Protein | 1 | 16.3** | 17.2 | 337.3* | 46,368.1** | 19.7** | .4 | 66.8** | 7.7 | 89.1 |
| Interaction | 1 | 3.8 | 16.0 | 449.0* | 3,828.2 | 1.1 | 15.9* | 46.4** | 37.9 | 10.6 |

* Significant at $P < 0.05$
** Significant at $P < 0.01$

TABLE 14A - 110 LB. PIG METABOLISM TRIAL - BODY WEIGHTS AND FEED[1] CONSUMPTION

| | | Gain in Wt. | | Av. Body Wt. | | Per 100 gm. Body Wt. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Rep. | Met. period | | Met. period | | Av. 5 day gain | Feed cons | A D E cons | Gross N cons |
| | | lb. | kg. | lb. | kg. | gm. | gm. | Cal. | mg. |
| Ration 1 | 1 | 10.5 | 4.8 | 104.8 | 47.5 | 10.0 | 21.9 | 95.8 | 633.5 |
| HE-HP | 2 | 7.5 | 3.4 | 110.2 | 50.0 | 6.8 | 18.7 | 81.8 | 541.0 |
| | 3 | 9.5 | 4.3 | 109.2 | 49.5 | 8.7 | 24.4 | 106.7 | 705.7 |
| | 4 | 11.0 | 5.0 | 107.5 | 48.8 | 10.2 | 24.5 | 106.9 | 707.2 |
| Mean | | 9.6 | 4.4 | 107.9 | 49.0 | 8.9 | 22.4 | 97.8 | 646.9 |
| Ration 2 | 1 | 5.5 | 2.5 | 106.8 | 48.4 | 5.1 | 25.4 | 89.5 | 598.5 |
| LE-LP | 2 | 11.5 | 5.2 | 100.8 | 45.7 | 11.4 | 25.2 | 89.0 | 595.2 |
| | 3 | 7.5 | 3.4 | 110.8 | 50.3 | 6.8 | 26.2 | 92.4 | 617.6 |
| | 4 | 13.5 | 6.1 | 115.8 | 52.5 | 11.6 | 27.5 | 97.1 | 649.2 |
| Mean | | 9.5 | 4.3 | 108.6 | 49.2 | 8.7 | 26.1 | 92.0 | 615.1 |
| Ration 3 | 1 | 8.5 | 3.9 | 108.8 | 49.4 | 7.8 | 23.6 | 83.4 | 663.7 |
| LE-HP | 2 | 6.0 | 2.7 | 107.0 | 48.5 | 5.6 | 24.9 | 87.8 | 699.1 |
| | 3 | - | - | - | - | - | - | - | - |
| | 4 | 7.0 | 3.2 | 112.5 | 51.0 | 6.2 | 27.1 | 95.6 | 761.0 |
| Mean | | 9.5 | 4.3 | 108.3 | 49.1 | 8.8 | 25.8 | 91.1 | 725.3 |
| Ration 4 | 1 | 8.0 | 3.6 | 110.0 | 49.9 | 7.3 | 19.9 | 86.4 | 435.8 |
| HE-LP | 2 | 9.0 | 4.1 | 126.5 | 57.4 | 7.1 | 20.7 | 89.9 | 453.8 |
| | 3 | - | - | - | - | - | - | - | - |
| | 4 | 14.0 | 6.4 | 136.0 | 61.7 | 10.3 | 20.3 | 88.1 | 444.6 |
| Mean | | 10.3 | 4.7 | 124.2 | 56.3 | 8.2 | 20.3 | 88.1 | 444.7 |

1 Oven-dry basis

[illegible]

TABLE 14B - 110 LB. PIG METABOLISM TRIAL - DRY MATTER, ENERGY AND NITROGEN DIGESTIBILITY; NITROGEN RETENTION

| | Rep | Digestibility | | | Corr. Digestibility | | Retention | |
|---|---|---|---|---|---|---|---|---|
| | | Dry matter | Energy | Nitrogen | Dry matter | Energy | Gross N | A D N |
| | | % | % | % | % | % | % | % |
| Ration 1 | 1 | 87 | 87 | 87 | 87 | 87 | 32 | 37 |
| HE-HP | 2 | 90 | 89 | 89 | 90 | 89 | 29 | 33 |
| | 3 | 89 | 89 | 88 | 89 | 89 | 40 | 45 |
| | 4 | 89 | 89 | 88 | 89 | 89 | 38 | 43 |
| Mean | | 89 | 89 | 88 | 89 | 89 | 35 | 39 |
| Ration 2 | 1 | 69 | 84 | 82 | 89 | 87 | 41 | 50 |
| LE-LP | 2 | 73 | 85 | 84 | 93 | 88 | 54 | 64 |
| | 3 | 68 | 84 | 81 | 87 | 87 | 33 | 41 |
| | 4 | 70 | 86 | 80 | 89 | 89 | 50 | 62 |
| Mean | | 70 | 85 | 82 | 89 | 88 | 45 | 54 |
| Ration 3 | 1 | 73 | 87 | 85 | 92 | 90 | 43 | 51 |
| LE-HP | 2 | 72 | 82 | 82 | 91 | 85 | 44 | 54 |
| | 3 | - | - | - | - | - | - | - |
| | 4 | 70 | 82 | 79 | 89 | 85 | 42 | 53 |
| Mean | | 72 | 84 | 83 | 91 | 87 | 43 | 53 |
| Ration 4 | 1 | 87 | 87 | 85 | 87 | 87 | 40 | 47 |
| HE-LP | 2 | 89 | 88 | 85 | 89 | 88 | 39 | 46 |
| | 3 | - | - | - | - | - | - | - |
| | 4 | 91 | 91 | 91 | 91 | 91 | 35 | 38 |
| Mean | | 89 | 89 | 87 | 89 | 89 | 38 | 44 |

TABLE 15. - 110 LB. PIG METABOLISM TRIAL - REPLICATE, RATION, ENERGY AND PROTEIN MEANS FOR TABLES 14A AND 14B

| | | Per 100 gm. Body Wt. | | | | Corr. Digestibility | | Retention | |
|---|---|---|---|---|---|---|---|---|---|
| | Av. body wt. met. period | Av. 5 day gain | ADE cons. | Gross N cons. | Nitrogen digest-ibility | Dry matter | Energy | Gross N | ADN |
| | kg. | gm. | Cal. | mg. | % | % | % | % | % |
| Replicate 1 | 48.8 | 7.6 | 88.8 | 582.9 | 85 | 89 | 88 | 39 | 46 |
| Replicate 2 | 50.4 | 7.7 | 87.2 | 572.3 | 85 | 91 | 88 | 42 | 49 |
| Replicate 3 | 49.9 | 7.7 | 99.6 | 661.7 | 84 | 88 | 88 | 36 | 43 |
| Replicate 4 | 53.5 | 9.6 | 96.9 | 640.5 | 85 | 90 | 88 | 41 | 49 |
| HE-HP Ration 1 | 49.0 | 8.9 | 97.8 | 646.9 | 88 | 89 | 89 | 35 | 39 |
| LE-LP Ration 2 | 49.2 | 8.7 | 92.0 | 615.1 | 82 | 89 | 88 | 45 | 54 |
| LE-HP Ration 3 | 49.1 | 8.8 | 91.1 | 725.3 | 83 | 91 | 87 | 43 | 53 |
| HE-LP Ration 4 | 56.3 | 8.2 | 88.1 | 444.7 | 87 | 89 | 89 | 38 | 44 |
| High energy rations 1 and 4 | 52.1 | 8.6 | 93.7 | 560.2 | 88 | 89 | 89 | 36 | 41 |
| Low energy rations 2 and 3 | 49.4 | 7.8 | 90.7 | 654.9 | 82 | 90 | 87 | 44 | 54 |
| High protein rations 1 and 3 | 49.2 | 7.9 | 94.0 | 673.0 | 85 | 90 | 88 | 38 | 45 |
| Low protein rations 2 and 4 | 52.3 | 8.5 | 90.4 | 542.1 | 84 | 89 | 88 | 42 | 50 |

TABLE 16. - 110 LB. PIG METABOLISM TRIAL - MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF TABLES 14A AND 14B

| | | | Per 100 gm. Body Wt. | | | Digestibility | | | Retention | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DF | Av. body wt. met. period | Av. 5 day gain | ADE cons. | Gross N cons. | Corr. dry matter | Corr. energy | Nitrogen | Gross N | ADN |
| Total | 13 | | | | | | | | | |
| Ration | 3 | 39.6* | 3.8 | 69.3 | 38,728.1** | 3.4 | 2.2 | 39.1* | 77.9 | 188.5 |
| Replicate | 3 | 15.8 | 3.6 | 119.3* | 5,869.9* | 3.2 | 0.5 | 0.5 | 15.0 | 21.9 |
| Error | 7 | 7.9 | 5.5 | 27.0 | 1,103.8 | 3.1 | 3.4 | 7.4 | 44.9 | 62.7 |
| Energy | 1 | 25.6 | 2.4 | 30.9 | 31,376.0** | 4.9 | 4.5 | 115.8** | 213.2 | 530.9* |
| Protein | 1 | 32.0 | 1.3 | 46.9 | 60,001.9** | 1.6 | 0.6 | 6.4 | 39.4 | 75.5 |
| Interaction | 1 | 61.2* | 7.8 | 130.1 | 24,806.2** | 3.7 | 1.4 | -4.9 | -19.0 | -40.9 |

* Significant at P $<$ 0.05
** Significant at P $<$ 0.01

[illegible]

[illegible]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

[illegible]

[illegible]

Protein level also influenced ADE consumption. Fifty pound pigs, acting in a manner similar to the rat, consumed significantly greater amounts of ADE when fed the HE-LP ration. This trend was not significant in 15 lb. pigs which had been on the ration for only a short time and it was not evident in 110 lb. pigs which require less nitrogen per unit of feed. In the 15 lb. group, as well as in the 50 lb. group for which the interaction was significant, there was a greater increase in ADE consumption when the energy content of LP rations was increased than there was when the energy content of HP rations was increased. This further indicated that starting and growing pigs may have consumed greater amounts of ADE in order to obtain more nitrogen.

2) Digestibility of Dry Matter and Energy

As in the rat trial dry matter and energy digestibility figures as given in Tables 8B, 11B and 14B were adjusted for moisture and diluent content. With the exception of the 15 lb. pigs these digestibility figures were the same for low as for high energy rations. The percent energy digestibility was lowered when rations containing Terralite were fed to 15 lb. pigs.

Dry matter and energy digestibilities on a percentage basis were lower for 50 lb. than for 15 and 110 lb. pigs. There was also a difference between replicates in dry matter and energy digestibilities in all but the 110 lb. group indicating between litter variation.

3) Consumption and Digestibility of Nitrogen

The nitrogen data along with analyses of the data are reported in Tables 8A to 16.

As would be expected from the type of ration formulation used,

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

pigs fed rations high in protein consumed more nitrogen than pigs fed low protein rations. On a 100 gm. body weight basis the greatest amount of nitrogen was consumed by pigs fed the LE-HP ration, the least by pigs fed the HE-LP ration. As low energy rations had a relatively lower energy to protein ratio, pigs fed rations low in energy consumed a greater amount of nitrogen than those fed high energy rations.

The percentage ADN did not increase significantly as the nitrogen level in the diet increased, except for 50 lb. pigs. The percentage ADN was higher, however, when high protein rations were fed to 15 and 110 lb. pigs.

In the 50 lb. group a significant interaction between energy and protein resulted as the increase in percentage ADN was not as great when the protein level of the low energy ration was increased as it was when the protein level of the high energy ration was raised. In the 15 lb. pigs increasing the protein level of low energy rations actually decreased the percentage ADN.

A significant decrease in percentage ADN occurred in all groups when low energy rations were fed, probably as a result of the diluent causing an increase in metabolic fecal nitrogen. This possible increase in M.F.N. with an increase in ration fiber was discussed in the rat trial.

4) Nitrogen Retention

Nitrogen retention as a percentage of gross nitrogen or ADN was significantly higher for 15 lb. pigs fed high protein rations than it was for pigs in the same group fed rations low in protein and high in energy. Similar findings have been reported by De Maeyer and

Vanderborght (1957), as cited by Scrimshaw *et al*. (1958), who showed that the biological value of soya (soybean oil meal) fed to children, as determined by nitrogen retention, was higher at high levels of intake than at low.

As indicated by a significant interaction between energy and protein in the ration of the 15 lb. pigs a higher percentage increase in nitrogen retention occurred when the protein level of the high energy ration was increased than occurred when the protein level of the low energy ration was raised. Nitrogen retention of the HE-HP ration (150 Cal. ADE/gm. ADN) was 13% higher than that of the HE-LP ration (200 Cal. ADE/gm. ADN). Nitrogen retention of the LE-HP ration (128 Cal. ADE/gm. ADN) was only 1 to 2% higher than that of the LE-LP ration (155 Cal. ADE/gm. ADN).

It appears that for 15 lb. pigs the energy/protein ratio is important in obtaining maximum nitrogen retention. In this study, nitrogen retention was lowered when the energy/protein ratio was higher than 150 Cal. ADE/gm. ADN. However, feeding too high a level of protein would probably also lower nitrogen retention as work with rats (Sibbald *et al*., 1957; Sure *et al*., 1957; Bowland *et al*., 1958) and swine (Bell and Loosli, 1951; Reber *et al*., 1953) has shown that, due to the greater waste in metabolism with the increased ingestion of protein, percent nitrogen retention will decrease if high levels of protein are fed.

Increasing the protein level of the high energy ration did not lower percent nitrogen retention by 50 lb. pigs, however, it was lowered when the protein level of the low energy ration was increased.

Increasing the protein level of both high and low energy rations lowered nitrogen retention of pigs in the 110 lb. group. Although these differences were not significant they indicated a trend toward less efficient use of protein when 50 and 110 lb. pigs were fed high protein rations.

In 15, 50 and 110 lb. pigs percent nitrogen retention was highest for the slower growing pigs fed low energy rations. This resulted despite a possible greater M.F.N. loss for these pigs than for those fed high energy rations.

### C. DAILY GAIN, DAILY FEED AND EFFICIENCY OF FEED UTILIZATION OF SWINE UP TO MARKET WEIGHT; CARCASS CHARACTERISTICS OF MARKET SWINE

Experiment 328A, to which the majority of the following results and discussion pertain, was conducted with four different breeding groups. However, as this project was primarily concerned with ration effects, the strain differences will not be discussed, although they were separated in the analysis.

Sex differences were determined for rate of gain and carcass characteristics. As the pigs in each lot were group fed, differences between sexes could not be determined for daily feed and efficiency of feed utilization.

An analysis of variance was done for Experiment 328 mainly to determine if the pigs in this trial, which were used in the metabolism study reported previously, behaved similarly to the pigs in Experiment 328A. When mentioned in the discussion data from Experiment 328 will be referred to specifically.

The term "feed" as used in the following discussion excludes the Terralite content of low energy rations.

1) Daily Gain

The data and statistical analysis of the data for daily gain are given in Tables 17 and 18 for Experiment 328A and in Tables 21 and 22 for Experiment 328.

Average daily gain was limited, especially in the early growth stage, by protein level. Up to 64 days of age significantly greater increases in rate of gain resulted when the protein level of the high energy ration was increased than occurred when the protein level of the low energy ration was raised. From 64 days to market weight pigs fed high energy rations made significantly greater weight gains than pigs fed rations low in energy. In general rate of gain from weaning to market weight was improved by increasing either the energy or protein content of the rations.

These results are in agreement with recently reported studies by Abernathy *et al*. (1958) who found that a highly significant increase in gains resulted when the energy levels of rations were increased, and Bowland and Berg (1959) who reported that rate of liveweight gain tended to be fastest in pigs fed HE-HP rations throughout the growing and finishing period.

For the first 64 days on trial female and male pigs gained in weight at the same rate. From 64 days to market weight males made faster gains than females, and males had a significantly higher daily rate of gain from weaning to market weight.

2) Daily Feed

The data and analysis for average daily feed are given in Tables 19 and 20 for Experiment 328A and in Tables 21 and 22 for Experiment 328.

TABLE 17. - EXPERIMENT 328A - AVERAGE DAILY GAIN IN WEIGHT OF 64 PIGS FROM WEANING TO MARKET WEIGHT

| | | No. of pigs | First 36 days on test | First 64 days on test | 64 days to market wt. | Summary: Weaning to market wt. |
|---|---|---|---|---|---|---|
| | | | lb. | lb. | lb. | lb. |
| Ration 1 | HE-HP | 16 | 1.14 | 1.36 | 1.89 | 1.59 |
| Ration 2 | LE-LP | 16 | 0.86 | 1.08 | 1.80 | 1.42 |
| Ration 3 | LE-HP | 16 | 0.95 | 1.19 | 1.72 | 1.43 |
| Ration 4 | HE-LP | 16 | 0.75 | 0.98 | 2.00 | 1.47 |
| Female | | 32 | 0.93 | 1.15 | 1.76 | 1.44 |
| Male | | 32 | 0.92 | 1.16 | 1.94 | 1.52 |

TABLE 18. - EXPERIMENT 328A - MEANS SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF INDIVIDUAL DATA SUMMARIZED IN TABLE 17

| | DF | First 36 days on test | First 64 days on test | 64 days to market wt. | Summary: Weaning to market wt. |
|---|---|---|---|---|---|
| Total | 63 | | | | |
| Sex | 1 | 0.00 | 0.01 | 0.49** | 0.10** |
| Strain | 3 | 0.10 | 0.09* | 0.17** | 0.08** |
| Ration | 3 | 0.43** | 0.42** | 0.23** | 0.09** |
| Ration x strain | 9 | 0.04 | 0.03 | 0.03 | 0.01 |
| Ration x sex | 3 | 0.09 | 0.07 | 0.06 | 0.03 |
| Strain x sex | 3 | 0.03 | 0.03 | 0.05 | 0.01 |
| Error | 41 | 0.05 | 0.03 | 0.03 | 0.01 |
| Energy | 1 | 0.03 | 0.02 | 0.53** | 0.16** |
| Protein | 1 | 0.92** | 0.95** | 0.14* | 0.06* |
| Interaction | 1 | 0.35** | 0.29** | 0.01 | 0.05 |

* Significant at $P < 0.05$
** Significant at $P < 0.01$

TABLE 19. - EXPERIMENT 328A - AVERAGE DAILY FEED INTAKE AND EFFICIENCY OF FEED UTILIZATION OF 64 PIGS

| | Daily Feed[1] | | | | Feed per lb. Gain | | | | DE per lb. Gain | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Summary | | | | Summary | | | | Summary |
| | First 36 days on test | Weaning to 110 lb. | 110 lb. to market wt. | Weaning to market wt. | First 36 days on test | Weaning to 110 lb. | 110 lb. to market wt. | Weaning to market wt. | First 36 days on test | Weaning to 110 lb. | 110 lb. to market wt. | Weaning to market wt. |
| | lb. | lb. | lb. | lb. | lb. | lb. | lb. | lb. | Therms | Therms | Therms | Therms |
| Ration 1 HE-HP | 2.2 | 3.1 | 5.7 | 4.1 | 2.0 | 2.3 | 3.0 | 2.6 | 3.4 | 3.9 | 5.3 | 4.6 |
| Ration 2 LE-LP | 1.7 | 2.9 | 5.7 | 4.0 | 2.0 | 2.4 | 3.2 | 2.8 | 3.4 | 4.2 | 5.6 | 4.8 |
| Ration 3 LE-HP | 1.8 | 2.9 | 5.6 | 4.0 | 1.9 | 2.3 | 3.3 | 2.8 | 3.2 | 3.9 | 5.6 | 4.7 |
| Ration 4 HE-LP | 1.8 | 2.9 | 5.9 | 3.9 | 2.4 | 2.5 | 2.9 | 2.7 | 4.1 | 4.3 | 5.0 | 4.6 |

[1] Oven-dry feed less diluent.

[illegible] AVERAGE DAILY [illegible]

| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

[illegible]

TABLE 20. - EXPERIMENT 328A - MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF GROUPS OF FOUR SUMMARIZED IN TABLE 19

| | | Daily Feed[1] | | | | Feed per lb. Gain | | | | DE per lb. Gain | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DF | First 36 days on test | Weaning to 110 lb. | 110 lb. to market wt. | Summary Weaning to market wt. | First 36 days on test | Weaning to 110 lb. | 110 lb. to market wt. | Summary Weaning to market wt. | First 36 days on test | Weaning to 110 lb. | 110 lb. to market wt. | Summary Weaning to market wt. |
| Total | 15 | | | | | | | | | | | | |
| Strain | 3 | 0.08* | 0.07 | 0.33* | 0.09* | 0.05 | 0.03 | 0.04 | 0.03 | 0.14 | 0.09 | 0.11 | 0.08 |
| Ration | 3 | 0.06* | 0.20** | 0.09 | 0.04* | 0.05 | 0.21** | 0.13** | 0.03 | 0.16 | 0.69** | 0.31** | 0.05 |
| Error | 9 | 0.01 | 0.02 | 0.07 | 0.02 | 0.01 | 0.01 | 0.02 | 0.01 | 0.04 | 0.03 | 0.05 | 0.03 |
| Energy | 1 | 0.06 | 0.24** | 0.09 | 0.01 | 0.00 | 0.21** | 0.33** | 0.09* | 0.03 | 0.96** | 0.73** | 0.09 |
| Protein | 1 | 0.06 | 0.26** | 0.16 | 0.05 | 0.14* | 0.30** | 0.05 | 0.01 | 0.43* | 0.87** | 0.13 | 0.04 |
| Interaction | 1 | 0.05 | 0.10 | 0.01 | 0.06 | 0.02 | 0.13** | 0.01 | 0.00 | 0.09 | 0.23* | 0.06 | 0.02 |

* Significant at $P < 0.05$
** Significant at $P < 0.01$

[1] Oven-dry feed less diluent.

TABLE 21. - EXPERIMENT 328 - AVERAGE DAILY GAIN IN WEIGHT AND EFFICIENCY OF FEED UTILIZATION OF 13 PIGS FROM WEANING TO MARKET WEIGHT

| | No.[2] of pigs | Av. daily gain | Av. daily feed[1] | Feed[1] per lb. gain | DE per lb. gain |
|---|---|---|---|---|---|
| | | lb. | lb. | lb. | Therms |
| Ration 1 HE-HP | 4 | 1.4 | 3.6 | 2.5 | 4.3 |
| Ration 2 LE-LP | 3 | 1.2 | 2.9 | 2.5 | 4.3 |
| Ration 3 LE-HP | 3 | 1.2 | 2.9 | 2.4 | 4.1 |
| Ration 4 HE-LP | 3 | 1.3 | 3.3 | 2.5 | 4.3 |

[1]Oven-dry feed less diluent.

[2]One of the 4 pigs in rations 2, 3 and 4 died before market.

TABLE 22. - EXPERIMENT 328 - MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF INDIVIDUAL DATA SUMMARIZED IN TABLE 21

| | DF | Av. daily gain | Av. daily feed[1] | Feed[1] per lb. gain | DE per lb. gain |
|---|---|---|---|---|---|
| Total | 12 | | | | |
| Ration | 3 | 0.06 | 0.37 | 0.01 | 0.04 |
| Replicate | 3 | 0.02 | 0.13 | 0.05 | 0.17* |
| Error | 6 | -0.00[3] | -0.01[3] | 0.01 | 0.03 |
| Energy | 1 | 0.16 | 0.01 | 0.00 | 0.05 |
| Protein | 1 | 0.02 | 0.06 | 0.01 | 0.03 |
| Interaction | 1 | -0.00 | 1.04 | 0.00 | 0.05 |

[1]Oven-dry feed less diluent.

[3]A negative mean square for error, resulting from an unequal number of pigs in rations and replicates, prevented a test of significance from being carried out for average daily gain and daily feed.

* Significant at $P < 0.05$

Daily feed consumption tended to correspond to daily rate of gain. From weaning to 110 lb., pigs fed the HE-HP ration consumed a greater amount of feed per day than pigs fed the other rations. From 110 lb. to market weight pigs fed the HE-LP ration tended to consume the greater amount of feed, but differences in feed consumption were not significant.

As pigs fed the HE-LP ration grew slowly at an early age and made rapid gains prior to market their daily feed from weaning to market tended to be lower than that of pigs fed the other rations. This is in contrast to Experiment 328 where the daily feed intake of pigs fed high energy rations was higher than that of pigs fed low energy rations.

3) <u>Feed and Digestible Energy per lb. Gain</u>

The data and analysis for efficiency of feed and DE utilization are given in Tables 19 and 20 for Experiment 328A and in Tables 21 and 22 for Experiment 328.

Feed and DE required per lb. gain followed similar trends. During the first 36 days on trial pigs fed high protein rations required significantly less feed and DE per lb. gain than pigs fed rations low in protein. Energy levels, however, did not affect efficiency of feed utilization (corrected for Terralite content) during this period.

From weaning to 110 lb. both high energy and high protein rations improved efficiency of feed utilization. During this period, raising the protein level of the high energy ration resulted in a greater decrease in feed and DE required per lb. gain than raising the protein level of the low energy rations.

In contrast to work reported by Bowland and Berg (1959) in which it was found that high protein alone or in combination with high energy rations improved efficiency of feed utilization in the finishing period, pigs in this experiment fed rations high in protein tended to utilize their feed less efficiently from 110 lb. to market weight than pigs fed low protein rations. As a result protein levels did not significantly alter feed and DE required per lb. gain from weaning to 110 lb. or from weaning to market. Pigs fed high energy rations in the finishing period utilized both their feed and the DE of the feed more efficiently than pigs fed low energy rations.

During the first 36 days on experiment the same amount of feed and DE per lb. gain was required by pigs fed the HE-HP ration as was required by pigs fed the LE-LP ration, the 2 rations with similar energy-protein ratios. It appeared that during early stages of growth, feed in the presence of a diluent was utilized as efficiently as when high energy rations were fed. The energy-protein ratio seemed to be the major factor influencing feed efficiency. At later stages of growth, efficiency of feed utilization tended to be improved for pigs fed rations high in energy.

In Experiment 328 pigs fed HE-HP, LE-LP and HE-LP rations required equal amounts of feed and DE per lb. gain from weaning to market. Significantly less DE and a smaller amount of feed per lb. gain were required by pigs fed the LE-HP ration. These observations are not in agreement with Experiment 328A. Although it is possible that strain was a factor, significant strain differences did not exist in Experiment 328A for efficiency of feed and DE utilization. There was a restriction

in feed intake in Experiment 328 as compared to Experiment 328A. Such a restriction commonly occurs when individually fed pigs are compared to self-fed pigs (Hussar and Bowland, 1959) and it is possible that this restriction might have influenced the results of Experiment 328.

4) Carcass Characteristics of Market Swine

The data and statistical analysis for carcass characteristics of market swine are given in Tables 23 and 24 for Experiment 328A and in Tables 25 and 26 for Experiment 328. In these experiments there were no significant differences between the market weight of male and female pigs or between pigs fed different rations.

Male and female pigs had similar dressing percentages, as did pigs fed rations at varying protein levels. Pigs fed rations high in energy had significantly higher dressing percentages and corresponding higher hot carcass weights than pigs fed rations low in energy. These observations agree with the report by Bowland and Berg (1959).

The pigs fed high energy rations had a greater depth of average backfat than those fed low energy rations. Covariance analysis was not conducted to see if this increase in fat thickness was associated with the increased carcass weight of the high energy pigs. Male pigs had a greater thickness of backfat than females.

In Experiment 328 pigs fed rations high in protein had less backfat than pigs fed low protein rations. An interaction also resulted as increasing the protein level of low energy rations decreased backfat more than increasing the protein level of high energy rations.

TABLE 23. - EXPERIMENT 328A - AVERAGE ADVANCED REGISTRY MEASUREMENTS AND SCORES FOR SWINE CARCASSES

| | No. of pigs. | Live market weight | Hot Dressed weight | Dressing percentage | Length of side | Av. fat; shldr., back and loin | Area of loin | Total A.R. score |
|---|---|---|---|---|---|---|---|---|
| | | lb. | lb. | % | in. | in. | sq. in. | % |
| Ration 1 HE-HP | 16 | 197 | 159 | 81 | 30.9 | 1.5 | 4.22 | 74 |
| Ration 2 LE-LP | 16 | 196 | 153 | 78 | 31.0 | 1.4 | 3.97 | 78 |
| Ration 3 LE-HP | 16 | 194 | 151 | 78 | 30.9 | 1.4 | 4.09 | 83 |
| Ration 4 HE-LP | 16 | 198 | 159 | 80 | 31.0 | 1.6 | 3.81 | 66 |
| Female | 32 | 196 | 155 | 79 | 31.1 | 1.4 | 4.31 | 83 |
| Male | 32 | 196 | 156 | 79 | 30.8 | 1.6 | 3.74 | 67 |

TABLE 24. - EXPERIMENT 328A - MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF INDIVIDUAL DATA SUMMARIZED IN TABLE 23

| | DF | Live market weight | Hot Dressed weight | Dressing percentage | Length of side | Av. fat; shldr., back and loin | Area of loin | Total A.R. score |
|---|---|---|---|---|---|---|---|---|
| Total | 63 | | | | | | | |
| Sex | 1 | 0 | 16 | 3.38 | 1.47* | 0.60** | 5.32** | 4176** |
| Breed | 3 | 84* | 62** | 7.18** | 0.84* | 0.19** | 1.27** | 933** |
| Ration | 3 | 38 | 243** | 34.58** | 0.03 | 0.19** | 0.50* | 810** |
| Ration x breed | 9 | 18 | 33* | 2.83 | 0.60* | 0.00 | 0.12 | 43 |
| Ration x sex | 3 | 62* | 41* | 2.00 | 0.68* | 0.01 | 0.05 | 50 |
| Breed x sex | 3 | 59* | 16 | 1.39 | 1.54** | 0.00 | 0.22 | 83 |
| Error | 41 | 20 | 13 | 1.38 | 0.22 | 0.02 | 0.12 | 134 |
| Energy | 1 | 70 | 702** | 100.76** | 0.00 | 0.49** | 0.00 | 1774** |
| Protein | 1 | 44 | 14 | 0.55 | 0.10 | 0.08 | 1.17** | 594* |
| Interaction | 1 | 1 | 12 | 2.43 | 0.00 | 0.00 | 0.33 | 62 |

* Significant at $P < 0.05$
** Significant at $P < 0.01$

TABLE 25. - EXPERIMENT 328 - AVERAGE ADVANCED REGISTRY MEASUREMENTS AND SCORES FOR SWINE CARCASSES

| | No.[1] of pigs | Live market weight | Hot Dressed weight | Dressing percentage | Length of side | Av. fat; shldr., back and loin | Area of loin | Total A.R. score |
|---|---|---|---|---|---|---|---|---|
| | | lb. | lb. | % | in. | in. | sq. in. | % |
| Ration 1 HE-HP | 4 | 198 | 160 | 81 | 30.1 | 1.5 | 4.18 | 73 |
| Ration 2 LE-LP | 3 | 195 | 148 | 76 | 30.4 | 1.4 | 3.97 | 82 |
| Ration 3 LE-HP | 3 | 196 | 146 | 74 | 30.3 | 1.1 | 3.82 | 88 |
| Ration 4 HE-LP | 3 | 200 | 159 | 79 | 30.3 | 1.5 | 3.52 | 71 |

[1] One of the 4 pigs in rations 2, 3 and 4 died before market.

TABLE 26. - EXPERIMENT 328 - MEAN SQUARES OBTAINED BY ANALYSIS OF VARIANCE OF INDIVIDUAL DATA SUMMARIZED IN TABLE 25

| | DF | Live market weight | Dressed weight | Dressing percentage | Length of side | Av. fat; shldr., back and loin | Area of loin | Total A.R. score |
|---|---|---|---|---|---|---|---|---|
| Total | 12 | | | | | | | |
| Ration | 3 | 21 | 171* | 26.39* | 0.06 | 0.08** | 0.27 | 209 |
| Replicate | 3 | 16 | 8 | 4.28 | 0.04 | 0.01 | 0.05 | 47 |
| Error | 6 | 34 | 20 | 2.94 | 0.34 | 0.01 | 0.33 | 57 |
| Energy | 1 | 54 | 499** | 71.33** | 0.07 | 0.11** | 0.00 | 572* |
| Protein | 1 | 0 | 0 | 0.18 | 0.07 | 0.05* | 0.25 | 25 |
| Interaction | 1 | 8 | 14 | 7.65 | 0.04 | 0.09* | 0.54 | 31 |

* Significant at $P < 0.05$
** Significant at $P < 0.01$

Loin area was independent of the level of energy in the ration but increased when the protein level was increased, and was higher for female than for male pigs. In Experiment 328 the increase in loin area when high levels of protein were fed was not significant. The observation that protein level in the ration influences loin area agrees with several recent reports including that of Bowland and Berg (1959).

Length of side was not affected by energy and protein level. Female pigs had significantly longer carcasses than males. In work reported by Bowland and Berg (1959) female pigs tended to be longer than males while in a study of performance traits of Canadian Yorkshire swine, Fredeen (1953) reported that female carcasses averaged 0.23 inches longer than male carcasses.

Pigs fed low energy and high protein rations had carcasses which gave higher total A.R. scores than pigs fed high energy and low protein rations respectively. Increasing the protein level did not significantly increase the total A.R. score in Experiment 328. Female carcasses outscored male carcasses in all factors measured.

## SUMMARY AND CONCLUSIONS

The following results were obtained when rations containing 2 levels of energy and 2 levels of protein were fed to rats and swine. Rations fed to swine had gross energy levels of 3.2 and 3.9 Cal./gm. and crude protein levels of 14 and 18 percent. Terralite, a finely ground aggregate of vermiculite, was used as a diluent in the low energy rations.

In the rat trial two additional low energy rations containing Alphacel, a non-nutritive cellulose, as a diluent were fed. Terralite compared favourably with Alphacel as a diluent, although there were differences in the effects which the 2 products had on digestibility.

1) Rat and Swine Metabolism Trials

In the rat and swine digestibility and retention studies rate of gain and feed consumption data were expressed on a per unit average body weight basis. This correction for body weight was necessary as rate of gain tended to be higher for animals fed rations high in energy and/or protein.

Indigestible materials in the ration tended to decrease energy consumption for both rats and swine. Less ADE was consumed by 50 lb. pigs when fed rations low in energy. At 15 and 110 lb., however, pigs were similar to rats in that ADE consumption was not significantly lowered when low energy rations were fed.

Protein level also influenced ADE consumption. Rats and 50 lb. pigs consumed greater amounts of ADE when fed the HE-LP ration than they did when fed other rations.

Percent dry matter and energy digestibility figures were corrected

for moisture and diluent content. Corrected dry matter and energy digestibility remained the same in the presence of Alphacel as on the control rations, but for rats and 15 lb. pigs decreased in the presence of Terralite. There were significant differences in dry matter and energy digestibility associated with litters and/or replicates in both species. Average dry matter, energy and nitrogen digestibilities were similar for rats and swine, although swine digestibility figures changed with the age of the pig.

The percentage ADN did not increase significantly as the nitrogen level in the diet was raised, except for 50 lb. pigs. However, when high protein rations were fed to rats and to 15 and 110 lb. pigs, ADN figures were higher than when low levels of protein were fed. ADN was decreased for both species when a diluent was used to lower the energy content of the ration.

On the basis of nitrogen retention weanling pigs required a higher level of protein in their ration than was required by weanling rats. As the diets had an energy-protein ratio below that required for maximum nitrogen utilization by rats, nitrogen retention as a percentage of gross or digestible nitrogen was low for all diets used in the rat trial. In the trial with 15 lb. pigs the percent nitrogen retention was increased by raising the protein level of the ration. Nitrogen retention for 15 lb. pigs was also affected by the energy-protein ratio. At later stages of growth in pigs nitrogen retention appeared to decrease when high levels of protein were fed.

In the rat trial retention of nitrogen as a percentage of gross or digestible nitrogen was lower on low energy than on high energy diets.

In contrast, nitrogen retention was higher on the low energy rations than on high energy rations fed to swine.

2) Rate of Gain and Efficiency of Feed Utilization by Swine

The average daily gain of pigs was increased when high protein rations were fed at an early age, but was retarded by high protein levels at later stages of growth. In the finishing period pigs fed high energy rations made greater weight gains than pigs fed rations low in energy. Rate of gain from weaning to market weight was generally improved by raising either the energy or protein content of the rations.

The efficiency of feed utilization was also improved by feeding high levels of protein during early stages of growth and by increasing the energy level of the ration at later stages. Feeding high levels of protein during the finishing period tended to decrease efficiency of feed utilization.

3) Carcass Characteristics of Market Swine

Carcasses from pigs fed high energy rations had a higher dressing percentage and more backfat than pigs fed rations low in energy. Loin area was independent of the level of energy in the ration but was increased when the protein level was raised. Length of side was not affected by the energy or protein level of the ration.

When the energy level of a ration was raised but the energy-protein ratio was held constant the pig carcasses had a greater depth of backfat. However, they also had a higher dressing percentage and an increased loin area. It appeared that carcass quality was not seriously affected by feeding high energy rations which contained corresponding high levels of protein.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

4) Rate of Gain, Efficiency of Feed Utilization and Carcass Characteristics of Female and Male Pigs

Rate of gain during the early stages of growth did not differ between sexes. Males, however, made faster gains from approximately 90 to 195 lb. liveweight and, therefore, had a higher daily rate of gain than females from weaning to market weight.

The dressing percentages of male and female pigs were similar. Carcasses from female pigs were longer, had less backfat, greater loin area and a higher total Advanced Registry score than those of male pigs.

BIBLIOGRAPHY

1. ABERNATHY, R. P., R. E. Sewell and R. L. Tarplay. Interrelationships of protein, lysine and energy in diets for growing swine. J. Animal Sci. 17: 635-639.

2. ADOLPH, E. F., 1947. Urges to eat and drink in rats. Am. J. Physiol. 151:110-125.

3. ALLISON, J. B., 1951. Interpretation of nitrogen balance data. Federation Proc. 10:676-683.

4. ALLISON, J. B., and J. A. Anderson, 1945. The relation between absorbed nitrogen, nitrogen balance and biological value of proteins in adult dogs. J. Nutrition 29:413-420.

5. Anonymous. 1948. Oxygen bomb calorimetry and oxygen bomb combustion methods. Parr Manual No. 120, Parr Instrument Co., Moline, Ill.

6. ASHTON, G. C., J. Kastelic, D. C. Acker, A. H. Jensen, H. M. Maddock, E. A. Kline and D. V. Catron. 1955. Different protein levels with and without antibiotics for growing-finishing swine: Effect on carcass leanness. J. Animal Sci. 14: 82-93.

7. Association of Official Agricultural Chemists. 1955. Official methods of analysis of the A.O.A.C. 8th Ed., Washington, D.C.

8. BARBER, R. S., R. Braude and K. G. Mitchell. 1957. Comparison of six different levels of feeding for fattening pigs. J. Agr. Sci. 48:347-354.

9. BELL, J. M., 1948. An adjustable cylindrical cage for use in metabolism studies with young pigs. J. Nutrition 35: 365-369.

10. BELL, J. M. and J. K. Loosli. 1951. Effect of body weight on the biological value of proteins for growing swine. J. Animal Sci. 10:50-56.

11. BENDITT, E. P., E. M. Humphreys, R. W. Wissler, C. H. Steffee, L. E. Frazier and P. R. Cannon. 1948. The dynamics of protein metabolism. I. The interrelationship between protein and caloric intakes and their influence upon the utilization of ingested protein for tissue synthesis by the adult protein depleted rat. J. Lab. Clin. Med. 33:257-268.

12. BERG, R. T. and J. P. Bowland, 1958. Restricted feed intake in market swine. Univ. of Alberta Press Bull., Edmonton Can. 43(2):4-5.

13. BOSSHARDT, D. K., and R. H. Barnes. 1946. Caloric intake and the utilization of dietary protein for growth. Federation Proc. 5:228 (Abst.).

14. BOWLAND, J. P., 1959. Energy-protein relationships in swine rations. Univ. of Alta. Press Bull., Edmonton, Can. 44(2):15-17.

15. BOWLAND, J. P. and R. T. Berg. 1959. Influence of strain and sex on the relationship of protein to energy in the rations of growing and finishing bacon hogs. Can. J. Animal Sci. 39: In press.

16. BOWLAND, J. P., I. R. Sibbald, R. T. Berg and N. Hussar. 1958. Influence of dietary fat on energy consumption and digestion and on nitrogen utilization of weanling rats. Can. J. Animal Sci. 38:187-193.

17. CALLOWAY, D. H. and H. Spector. 1955. Nitrogen utilization during caloric restriction. I. The effect of dietary fat content. J. Nutrition 56:533-544.

18. CASTLE, E. J. and M. E. Castle. 1957. Further studies on the rate of passage of food through the alimentary tract of pigs. J. Agr. Sci. 49:106-112.

19. CATRON, D. V., A. H. Jensen, P. G. Homeyer, H. M. Maddock and G. C. Ashton. 1952. Re-evaluation of protein requirements of growing-fattening swine as influenced by feeding an antibiotic. J. Animal Sci. 11:221-232.

20. COWGILL, G. R., 1928. The energy factor in relation to food intake: Experiments on the dog. Am. J. Physiol. 85:45-64.

21. CRAMPTON, E. W., V. G. MacKay and L. E. Lloyd. 1955. The biological value of protein and the apparent digestibility of the crude fiber of malt sprouts. J. Animal Sci. 14:688-692.

22. CRAMPTON, E. W., and F. Whiting. 1943. The digestibility of typical eastern Canadian feeds by market bacon hogs. Sci. Agr. 23:518-526.

23. DANSKY, L. M. and F. W. Hill. 1951. The effect of energy level and physical nature of the diet on growth and body composition of chicks. Poultry Sci. 30:910(Abst.).

24. DONALDSON, W. E., G. F. Combs and G. L. Romoser. 1956. Studies on energy levels in poultry rations I. The effect of calorie-protein ratio of the ration on growth, nutrient utilization and body composition of chicks. Poultry Sci. 35:1100-1105.

25. ELLIS, N. R. and O. G. Hankins. 1935. The influence of protein content of the ration on the growth and fattening of hogs fed at a moderately restricted level. Proc. Am. Soc.Prod. 28:107-111.

26. FENTON, P. F. and J. M. Marsh. 1956. Inherited metabolic patterns in mice. Caloric requirements for protein utilization and determination of protein minima. J. Nutrition 60: 465-72.

27. FORBES, R. M. and M. Yohe. 1955. Effect of energy intake on the biological value of protein fed to rats. J. Nutrition 55:499-506.

28. FORBES, R. M., L. Vaughan and M. Yohe. 1958. Dependence of biological value on protein concentration in the diet of the growing rat. J. Nutrition 64:291-302.

29. FREDEEN, H. T., 1953. Genetic aspects of Canadian bacon production. Canada Dept. Agr. Pub. 889, Ottawa, Canada.

30. GOULDEN, C. H., 1956. Methods of statistical analysis, 2nd Ed. John Wiley and Sons, Inc., London.

31. HILL, F. W., and L. M. Dansky. 1950. Studies of the protein requirements of chicks and its relation to dietary energy level. Poultry Sci. 29:763(Abst.).

32. HILL, F. W., and L. M. Dansky. 1954. Studies of the energy requirements of chickens. I. The effect of dietary energy level on growth and feed consumption. Poultry Sci. 33:112-119.

33. HOEFER, J. A., R. W. Luecke, F. Thorp, Jr. and R. L. Johnston. 1952. The effect of terramycin on the growth of pigs fed different levels of protein. J. Animal Sci. 11:455-458.

34. HUSSAR, N., 1958. Rapeseed oil meal studies with swine and rats. M. Sc. Thesis. Univ. of Alta., Edmonton, Canada.

35. HUSSAR, N. and J. P. Bowland. 1959. Rapeseed oil meal as a protein supplement for swine and rats. II. Energy and nitrogen digestibility and nitrogen retention. Can. J. Animal Sci. 39: In press.

36. KEITH, T. B., and R. C. Miller. 1939. The protein requirements of the young pig. Proc. Am. Soc. Animal Proc. 32: 128-132.

37. KENNEDY, G. C., 1952-53. The role of depot fat in the hypothalmic control of food intake in the rat. Proc. Roy. Soc. B. 140-578-592.

38. KOLARI, O. E., E. A. Rutledge and L. E. Hanson. 1955. New equipment for baby pig metabolism studies. J. Animal Sci. 14:636-641.

39. LEVERTON, R. M., M. R. Gram and M. Chaloupka. 1951 Effect of the time factor and calorie level on nitrogen utilization of young women. J. Nutrition 44:537-545.

40. LLOYD, L. E. and E. W. Crampton. 1955. The apparent digestibility of the crude protein of the pig ration as a function of its crude protein and crude fiber content. J. Animal Sci. 14:693-699.

41. McMEEKAN, C. P., 1940. Growth and development in the pig with special reference to carcass quality characters. Part. III. Effect of the plane of nutrition on the form and composition of the bacon pig. J. Agr. Sci. 30:511-569.

42. MITCHELL, H. H. and T. S. Hamilton. 1935. The balancing of rations with respect to protein. Proc. Am. Soc. Animal Prod. 28:241-252.

43. MRAZ, F. R., R. V. Boucher and M. G. McCartney. 1957. The influence of the energy: volume ratio on growth response in chickens. Poultry Sci. 36:1217-1221.

44. National Bacon Hog Policy. 1954. Record of performance and Advanced Registry for purebred swine. Production Services, Dept. of Agr. Ottawa, Canada.

45. PETERSON, D. W., C. R. Grau, and N. F. Peek. 1954. Growth and food consumption in relation to dietary levels of protein and fibrous bulk. J. Nutrition 52:241-257.

46. PIKE, R. L., H. B. Suder and M. L. Ross. 1954. The influence of protein and energy intakes upon nitrogen retention in the pregnant rat. J. Nutrition 52:297-309.

47. POLLACK, H., 1954. Amino acids and protein therapy. Symposium on Protein Metabolism, the National Vitamin Foundation Inc., N.Y.

48. REBER, E. F., C. K. Whitehair and R. MacVicar. 1953. The effect of levels of protein fed baby pigs. J. Nutrition 50: 451-458.

49. ROBBLEE, A. R., and D. R. Clandinin. 1959. The relationship of energy and protein to reproductive performance in turkey breeders. Poultry Sci. 38:141-145.

50. ROBISON, W. L., 1940. Effects of high protein on pigs. Proc. Am. Soc. Animal Prod. 33:149-152.

51. ROBISON, W. L., L. E. Kunkle and V. R. Cahill. 1952. The influence of various factors on the yields of pork cuts. J. Animal Sci. 11:752 (Abst.).

52. ROSENTHAL, H. L., and J. B. Allison. 1951. Some effects of caloric intake on nitrogen balance in dogs. J. Nutrition 44: 423-431.

53. ROSENTHAL, H. L., and J. B. Allison. 1956. Effect of caloric intake on nitrogen balance and organ composition of adult rats. J. Agr. Food Chem. 4:792-796.

54. SCHWIMMER, D. and T. H. McGavack. 1948. Some newer aspects of protein metabolism. N.Y. State J. Med. 48:1797-1802.

55. SCRIMSHAW, N. S., G. Arroyave and R. Bressani. 1958. Biological value of foodstuffs and diets. Ann. Rev. Biochem. 27: 405-407.

56. SIBBALD, I. R., 1957. Energy and nitrogen in the food of the weanling rat. Ph.D. thesis, Univ. of Alta., Edmonton, Canada.

57. SIBBALD, I. R., R. T. Berg and J. P. Bowland. 1956. Digestible energy in relation to food intake and nitrogen retention in the weanling rat. J. Nutrition 59:385-392.

58. SIBBALD, I. R., J. P. Bowland, A. R. Robblee and R. T. Berg. 1957. Apparent digestible energy and nitrogen in the food of the weanling rat. Influence on food consumption, nitrogen retention and carcass composition. J. Nutrition 61: 71-86.

59. SIBBALD, I. R., J. P. Bowland, A. R. Robblee and R. T. Berg. 1957b. The influence of the nitrogen source on the food intake and nitrogen retention of weanling rats. J. Nutrition 62:185-200.

60. STEVENSON, G., P. P. Swanson, W. Willman and M. Brush. 1946. Nitrogen metabolism as influenced by level of caloric intake, character of diet and nutritional state of animal. Federation Proc. 5:240 (Abst.).

61. SUNDE, M. L. 1956. A relationship between protein level and energy level in chick rations. Poultry Sci. 35:350-354.

62. SURE, B. 1957. Relative nutritive values of proteins in various foods at increasingly high levels of protein intake. J. Agr. Food Chem. 5:463-464.

63. TERRILL, S. W., W. K. Warden, D. E. Becker and P. B. Beamer. 1952. The effect of feeding a high level of crude protein in drylot rations of fattening hogs. J. Am. Vet. Med. Assoc. 121:304-305.

64. TRIBBLE, L. F., W. H. Pfander, J. F. Lasley, S. E. Zobrisky and D. E. Brady. 1956. Factors affecting growth, feed efficiency and carcass in swine. Research Bull. 609. Univ. of Missouri, Coll. of Agr. Expt. Sta. Columbia, Missouri.

65. WATSON, C. J., J. A. Campbell, W. M. Davidson, C. H. Robinson and G. W. Muir. 1943. Digestibility studies with swine. I. The digestibility of grains and concentrates at different stages of the growing and fattening period. Sci. 23:708-724.

66. WHITING, F., and L. M. Bezeau. 1957. The metabolic fecal nitrogen excretion of the pig as influenced by the amount of fibre in the ration and by body weight. Can. J. Animal Sci. 37:95-105.